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<b>(21) International Application Number:</b> PCT/US96/20090 <b>(22) International Filing Date:</b> 13 December 1996 (13.12.96)  <b>(30) Priority Data:</b> 08/572,027 14 December 1995 (14.12.95) US  <b>(60) Parent Application or Grant</b> (63) Related by Continuation US 08/572,027 (CON) Filed on 14 December 1995 (14.12.95)  <b>(71) Applicant (for all designated States except US):</b> CARGILL, INCORPORATED [US/US]; 15407 McGinty Road West, Wayzata, MN 55391 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> DeBONTE, R., Lorin [US/US]; 3706 Rochdale Drive, Fort Collins, CO 80525 (US). FAN, Zhongong [US/US]; 4429 Monte Carlo Place, Fort Collins, CO 80525 (US). LOH, H.-T., Willie [US/US]; 5236 West Lake Nokomis Parkway, Minneapolis, MN 55417 (US).		<b>(74) Agent:</b> LUNDQUIST, C., Ronald; Fish & Richardson P.C., Suite 3300, 60 South 6th Street, Minneapolis, MN 55402 (US).  <b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the</i> <i>claims and to be republished in the event of the receipt of</i> <i>amendments.</i>	
<b>(54) Title:</b> PLANTS HAVING MUTANT SEQUENCES THAT CONFER ALTERED FATTY ACID PROFILES			
<b>(57) Abstract</b>  Seeds, plants and oils are provided having low FDA saturates; high oleic acid; low linoleic acid; high or low palmitic acid; low stearic acid; and low linoleic acid plus linolenic acid; and advantageous functional or nutritional properties. Plants are disclosed that contain a mutation in a delta-12 or delta-15 fatty acid desaturase gene. Preferred plants are rapeseed and sunflower plants. Plants carrying such mutant genes have altered fatty acid composition in seeds. In one embodiment, a plant contains a mutation in a region having the conserved motif His-Xaa-Xaa-Xaa-His, found in delta-12 and delta-15 fatty acid desaturases. A preferred motif has the sequence His-Glu-Cys-Gly-His. A preferred mutation in this motif has the amino acid sequence His-Lys-Cys-Gly-His. Nucleic acid fragments are disclosed that comprise a mutant delta-12 or delta-15 fatty acid desaturase gene sequence.			

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5        PLANTS HAVING MUTANT SEQUENCES THAT CONFER ALTERED  
         FATTY ACID PROFILES

Technical Field

         This invention relates to *Brassica* seeds and plants having mutant sequences which confer altered fatty acid profiles on the seed oil. More particularly, the  
10 invention relates to mutant delta-12 and delta-15 fatty acid desaturase sequences in such plants which confer such profiles.

Background of the Invention

         Diets high in saturated fats increase low density  
15 lipoproteins (LDL) which mediate the deposition of cholesterol on blood vessels. High plasma levels of serum cholesterol are closely correlated with atherosclerosis and coronary heart disease (Conner et al., *Coronary Heart Disease: Prevention, Complications,*  
20 *and Treatment*, pp. 43-64, 1985). By producing oilseed *Brassica* varieties with reduced levels of individual and total saturated fats in the seed oil, oil-based food products which contain less saturated fats can be produced. Such products will benefit public health by  
25 reducing the incidence of atherosclerosis and coronary heart disease.

         The dietary effects of monounsaturated fats have also been shown to have dramatic effects on health. Oleic acid, the only monounsaturated fat in most edible  
30 vegetable oils, lowers LDL as effectively as linoleic acid, but does not affect high density lipoproteins (HDL) levels (Mattson, F.H., *J. Am. Diet. Assoc.*, 89:387-391, 1989; Mensink et al., *New England J. Med.*, 321:436-441, 1989). Oleic acid is at least as effective in lowering  
35 plasma cholesterol as a diet low in fat and high in

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- carbohydrates (Grundy, S.M., New England J. Med., 314:745-748, 1986; Mensink et al., New England J. Med., 321:436-441, 1989). In fact, a high oleic acid diet is preferable to low fat, high carbohydrate diets for
- 5 diabetics (Garg et al., New England J. Med., 319:829-834, 1988). Diets high in monounsaturated fats are also correlated with reduced systolic blood pressure (Williams et al., J. Am. Med. Assoc., 257:3251-3256, 1987). Epidemiological studies have demonstrated that the
- 10 "Mediterranean" diet, which is high in fat and monounsaturates, is not associated with coronary heart disease (Keys, A., Circulation, 44(Suppl):1, 1970).
- Many breeding studies have been conducted to improve the fatty acid profile of Brassica varieties.
- 15 Pleines and Freidt, Fat Sci. Technol., 90(5), 167-171 (1988) describe plant lines with reduced  $C_{18:3}$  levels (2.5-5.8%) combined with high oleic content (73-79%). Rakow and McGregor, J. Amer. Oil Chem. Soc., 50, 400-403 (Oct. 1973) discuss problems associated with selecting mutants
- 20 for linoleic and linolenic acids. In. Can. J. Plant Sci., 68, 509-511 (Apr. 1988) Stellar summer rape producing seed oil with 3% linolenic acid and 28% linoleic acid is disclosed. Roy and Tarr, Z. Pflanzenzuchtg, 95(3), 201-209 (1985) teaches transfer of
- 25 genes through an interspecific cross from *Brassica juncea* into *Brassica napus* resulting in a reconstituted line combining high linoleic with low linolenic acid content. Roy and Tarr, Plant Breeding, 98, 89-96 (1987) discuss prospects for development of *B. napus* L. having improved
- 30 linolenic and linolenic acid content. European Patent application 323,751 published July 12, 1989 discloses seeds and oils having greater than 79% oleic acid combined with less than 3.5% linolenic acid. Canvin, Can. J. Botany, 43, 63-69 (1965) discusses the effect of

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temperature on the fatty acid composition of oils from several seed crops including rapeseed.

Mutations typically are induced with extremely high doses of radiation and/or chemical mutagens (Gaul, 5 H. Radiation Botany (1964) 4:155-232). High dose levels which exceed LD50, and typically reach LD90, led to maximum achievable mutation rates. In mutation breeding of *Brassica* varieties high levels of chemical mutagens alone or combined with radiation have induced a limited 10 number of fatty acid mutations (Rakow, G.Z. Pflanzenzuchtg (1973) 69:62-82). The low  $\alpha$ -linolenic acid mutation derived from the Rakow mutation breeding program did not have direct commercial application because of low seed yield. The first commercial cultivar 15 using the low  $\alpha$ -linolenic acid mutation derived in 1973 was released in 1988 as the variety Stellar (Scarth, R. et al., Can. J. Plant Sci. (1988) 68:509-511). Stellar was 20% lower yielding than commercial cultivars at the time of its release.

20 Canola-quality oilseed *Brassica* varieties with reduced levels of saturated fatty acids in the seed oil could be used to produce food products which promote cardiovascular health. Canola lines which are individually low in palmitic and stearic acid content or 25 low in combination will reduce the levels of saturated fatty acids. Similarly, *Brassica* varieties with increased monounsaturate levels in the seed oil, and products derived from such oil, would improve lipid nutrition. Canola lines which are low in linoleic acid 30 tend to have high oleic acid content, and can be used in the development of varieties having even higher oleic acid content.

Increased palmitic acid content provides a functional improvement in food applications. Oils high 35 in palmitic acid content are particularly useful in the

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formulation of margarines. Thus, there is a need for manufacturing purposes for oils high in palmitic acid content.

Decreased  $\alpha$ -linolenic acid content provides a functional improvement in food applications. Oils which are low in linolenic acid have increased stability. The rate of oxidation of lipid fatty acids increases with higher levels of linolenic acid leading to off-flavors and off-odors in foods. There is a need in the food industry for oils low in alpha linolenic acid.

Delta-12 fatty acid desaturase (also known as oleic desaturase) is involved in the enzymatic conversion of oleic acid to linoleic acid. Delta-15 fatty acid desaturase (also known as linoleic acid desaturase) is involved in the enzymatic conversion of linoleic acid to  $\alpha$ -linolenic acid. A microsomal delta-12 desaturase has been cloned and characterized using T-DNA tagging. Okuley, et al., Plant Cell 6:147-158 (1994). The nucleotide sequences of higher plant genes encoding microsomal delta-12 fatty acid desaturase are described in Lightner et al., WO94/11516. Sequences of higher plant genes encoding microsomal and plastid delta-15 fatty acid desaturases are disclosed in Yadav, N., et al., Plant Physiol., 103:467-476 (1993), WO 93/11245 and Arondel, V. et al., Science, 258:1353-1355 (1992). However, there are no teachings that disclose mutations in delta-12 or delta-15 fatty acid desaturase coding sequences from plants. Furthermore, no methods have been described for developing plant lines that contain delta-12 or delta-15 fatty acid desaturase gene sequence mutations effective for altering the fatty acid composition of seeds.

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Summary of the Invention

The present invention comprises canola seeds, plant lines producing seeds, and plants producing seed, said seeds having a maximum content of FDA saturates of about 5% and a maximum erucic acid content of about 2% based upon total extractable oil and belonging to a line in which said saturates content has been stabilized for both the generation to which the seed belongs and its parent generation. Progeny of said seeds and canola oil having a maximum erucic acid content of about 2%, based upon total extractable oil, are additional aspects of this invention. Preferred are seeds, plant lines producing seeds, and plants producing seeds, said seeds having an FDA saturates content of from about 4.2% to about 5.0% based upon total extractable oil.

The present invention further comprises *Brassica* seeds, plant lines producing seeds, and plants producing seeds, said seeds having a minimum oleic acid content of about 71% based upon total extractable oil and belonging to a line in which said oleic acid content has been stabilized for both the generation to which the seed belongs and its parent generation. A further aspect of this invention is such high oleic acid seeds additionally having a maximum erucic acid content of about 2% based upon total extractable oil. Progeny of said seeds; and *Brassica* oil having 1) a minimum oleic acid content of about 71% or 2) a minimum oleic acid content of about 71% and a maximum erucic content of about 2% are also included in this invention. Preferred are seeds, plant lines producing seeds, and plants producing seeds, said seeds having an oleic acid content of from about 71.2% to about 78.3% based upon total extractable oil.

The present invention further comprises canola seeds, plant lines producing seeds, and plants producing seeds, said seeds having a maximum linoleic acid content

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of about 14% and a maximum erucic acid content of about 2% based upon total extractable oil and belonging to a line in which said acid content is stabilized for both the generation to which the seed belongs and its parent  
5 generation. Progeny of said seeds and canola oil having a maximum linoleic acid content of about 14% and a maximum erucic acid content of about 2%, are additional aspects of this invention. Preferred are seeds, plant lines producing seeds, and plants producing seeds, said  
10 seeds having a linoleic acid content of from about 8.4% to about 9.4% based upon total extractable oil.

The present invention further comprises *Brassica* seeds, plant lines producing seeds, and plants producing seeds, said seeds having a maximum palmitic acid content  
15 of about 3.5% and a maximum erucic acid content of about 2% based on total extractable oil and belonging to a line in which said acid content is stabilized for both the generation to which the seed belongs and its parent generation. Progeny of said seeds and canola having a  
20 maximum palmitic acid content of about 3.5% and a maximum erucic acid content of about 2%, are additional aspects of this invention. Preferred are seeds, plant lines producing seeds, and plants producing seeds, said seeds having a palmitic acid content of from about 2.7% to  
25 about 3.1% based upon total extractable oil.

The present invention further comprises *Brassica* seeds, plant lines producing seeds, and plants producing seeds, said seeds having a minimum palmitic acid content of about 9.0% based upon total extractable oil and  
30 belonging to a line in which said acid content is stabilized for both the generation to which the seed belongs and its parent generation. A further aspect of this invention is such high palmitic acid seeds additionally having a maximum erucic acid content of  
35 about 2% based upon total extractable oil. Progeny of



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said seeds; and *Brassica* oil having 1) a minimum palmitic acid content of about 9.0%, or 2) a minimum palmitic acid content of about 9.0% and a maximum erucic acid content of about 2% are also included in this invention.

5 Preferred are seeds, plant lines producing seeds, and plants producing seeds, said seeds having a palmitic acid content of from about 9.1% to about 11.7% based upon total extractable oil.

The present invention further comprises *Brassica*  
10 seeds, plant lines producing seeds, and plants producing seeds, said seeds having a maximum stearic acid content of about 1.1% based upon total extractable oil and belonging to a line in which said acid content is stabilized for both the generation to which the seed  
15 belongs and its parent generation. Progeny of said seeds have a canola oil having a maximum stearic acid content of about 1.1% and maximum erucic acid content of about 2%. Preferred are seeds, plant lines producing seeds, and plants producing seeds having a palmitic acid content  
20 of from about 0.8% to about 1.1% based on total extractable oil.

The present invention further comprises *Brassica*  
seeds, plant lines producing seeds, and plants producing seeds, said seeds having a sum of linoleic acid content  
25 and linolenic acid content of a maximum of about 14% based upon total extractable oil and belonging to a line in which said acid content is stabilized for both the generation to which the seed belongs and its parent generation. Progeny of said seeds have a canola oil  
30 having a sum of linoleic acid content and linolenic acid content of a maximum of about 14% and a maximum erucic acid content of about 2%. Preferred are seeds, plant lines producing seeds, and plants producing seeds having a sum of linoleic acid content and linolenic acid content

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of from about 11.8% to about 12.5% based on total extractable oil.

The invention further comprises *Brassicaceae* or *Helianthus* seeds, plants and plant lines having at least  
5 one mutation that controls the levels of unsaturated fatty acids in plants. One embodiment of the invention is an isolated nucleic acid fragment comprising a nucleotide sequence encoding a mutant delta-12 fatty acid desaturase conferring altered fatty composition in seeds  
10 when the fragment is present in a plant. A preferred sequence comprises a mutant sequence as shown in SEQ ID NO:3. Another embodiment of the invention is an isolated nucleic acid fragment comprising a nucleotide sequence encoding a mutant delta-15 fatty acid desaturase. A  
15 plant in this embodiment may be soybean, oilseed *Brassica* species, sunflower, castor bean or corn. The mutant sequence may be derived from, for example, a *Brassica napus*, *Brassica rapa*, *Brassica juncea* or *Helianthus* delta-12 or delta-15 gene.

20 Another embodiment of the invention involves a method of producing a *Brassicaceae* or *Helianthus* plant line comprising the steps of: (a) inducing mutagenesis in cells of a starting variety of a *Brassicaceae* or *Helianthus* species; (b) obtaining progeny plants from the  
25 mutagenized cells; (c) identifying progeny plants that contain a mutation in a delta-12 or delta-15 fatty acid desaturase gene; and (d) producing a plant line by selfing.

Yet another embodiment of the invention involves a  
30 method of producing plant lines containing altered levels of unsaturated fatty acids comprising: (a) crossing a first plant with a second plant having a mutant delta-12 or delta-15 fatty acid desaturase; (b) obtaining seeds from the cross of step (a); (c) growing fertile plants  
35 from such seeds; (d) obtaining progeny seed the plants of

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step (c); and (e) identifying those seeds among the progeny that have altered fatty acid composition. Suitable plants are soybean, rapeseed, sunflower, safflower, castor bean and corn. Preferred plants are rapeseed and sunflower.

The invention is also embodied in vegetable oil obtained from plants disclosed herein, which vegetable oil has an altered fatty acid composition.

#### Brief Description of the Figures

Figure 1 is a histogram showing the frequency distribution of seed oil oleic acid ( $C_{18:1}$ ) content in a segregating population of a Q508 X Westar cross. The bar labeled WSGA 1A represents the  $C_{18:1}$  content of the Westar parent. The bar labeled Q508 represents the  $C_{18:1}$  content of the Q508 parent.

#### Description of the Preferred Embodiments

The U.S. Food and Drug Administration defines saturated fatty acids as the sum of lauric ( $C_{12:0}$ ), myristic ( $C_{14:0}$ ), palmitic ( $C_{16:0}$ ) and stearic ( $C_{18:0}$ ) acids. The term "FDA saturates" as used herein means this above-defined sum. Unless total saturate content is specified, the saturated fatty acid values expressed here include only "FDA saturates."

All percent fatty acids herein are percent by weight of the oil of which the fatty acid is a component.

As used herein, a "line" is a group of plants that display little or no genetic variation between individuals for at least one trait. Such lines may be created by several generations of self-pollination and selection, or vegetative propagation from a single parent using tissue or cell culture techniques. As used herein, the term "variety" refers to a line which is used for commercial production.

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The term "mutagenesis" refers to the use of a mutagenic agent to induce random genetic mutations within a population of individuals. The treated population, or a subsequent generation of that population, is then  
5 screened for usable trait(s) that result from the mutations. A "population" is any group of individuals that share a common gene pool. As used herein "M<sub>0</sub>" is untreated seed. As used herein, "M<sub>1</sub>" is the seed (and resulting plants) exposed to a mutagenic agent, while "M<sub>2</sub>"  
10 is the progeny (seeds and plants) of self-pollinated M<sub>1</sub> plants, "M<sub>3</sub>" is the progeny of self-pollinated M<sub>2</sub> plants, and "M<sub>4</sub>" is the progeny of self-pollinated M<sub>3</sub> plants. "M<sub>5</sub>" is the progeny of self-pollinated M<sub>4</sub> plants. "M<sub>6</sub>", "M<sub>7</sub>", etc. are each the progeny of self-pollinated plants  
15 of the previous generation. The term "selfed" as used herein means self-pollinated.

"Stability" or "stable" as used herein means that with respect to a given fatty acid component, the component is maintained from generation to generation for  
20 at least two generations and preferably at least three generations at substantially the same level, e.g., preferably  $\pm 5\%$ . The method of invention is capable of creating lines with improved fatty acid compositions stable up to  $\pm 5\%$  from generation to generation. The  
25 above stability may be affected by temperature, location, stress and time of planting. Thus, comparison of fatty acid profiles should be made from seeds produced under similar growing conditions. Stability may be measured based on knowledge of prior generation.

30 Intensive breeding has produced Brassica plants whose seed oil contains less than 2% erucic acid. The same varieties have also been bred so that the defatted meal contains less than 30  $\mu\text{mol}$  glucosinolates/gram. "Canola" as used herein refers to plant variety seed or

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oil which contains less than 2% erucic acid ( $C_{22:1}$ ), and meal with less than 30  $\mu\text{mol}$  glucosinolates/gram.

Applicants have discovered plants with mutations in a delta-12 fatty acid desaturase gene. Such plants  
5 have useful alterations in the fatty acid compositions of the seed oil. Such mutations confer, for example, an elevated oleic acid content, a decreased, stabilized linoleic acid content, or both elevated oleic acid and decreased, stabilized linoleic acid content.

10 Applicants have further discovered plants with mutations in a delta-15 fatty acid desaturase gene. Such plants have useful alterations in the fatty acid composition of the seed oil, e.g., a decreased, stabilized level of  $\alpha$ -linolenic acid.

15 Applicants have further discovered isolated nucleic acid fragments comprising sequences that carry mutations within the coding sequence of delta-12 or delta-15 desaturases. The mutations confer desirable alterations in fatty acid levels in the seed oil of  
20 plants carrying such mutations. Delta-12 fatty acid desaturase is also known as omega-6 fatty acid desaturase and is sometimes referred to herein as 12-DES. Delta-15 fatty acid desaturase is also known as omega-3 fatty acid desaturase and is sometimes referred to herein as 15-DES.

25 A nucleic acid fragment of the invention contains a mutation in a microsomal delta-12 fatty acid desaturase coding sequence or in a microsomal delta-15 fatty acid desaturase coding sequence. Such a mutation renders the resulting desaturase gene product non-functional in  
30 plants, relative to the function of the gene product encoded by the wild-type sequence. The non-functionality of the 12-DES gene product can be inferred from the decreased level of reaction product (linoleic acid) and increased level of substrate (oleic acid) in plant  
35 tissues expressing the mutant sequence, compared to the

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corresponding levels in plant tissues expressing the wild-type sequence. The non-functionality of the 15-DES gene product can be inferred from the decreased level of reaction product ( $\alpha$ -linolenic acid) and the increased  
5 level of substrate (linoleic acid) in plant tissues expressing the mutant sequence, compared to the corresponding levels in plant tissues expressing the wild-type sequence.

A nucleic acid fragment of the invention may  
10 comprise a portion of the coding sequence, e.g., at least about 10 nucleotides, provided that the fragment contains at least one mutation in the coding sequence. The length of a desired fragment depends upon the purpose for which the fragment will be used, e.g., PCR primer, site-  
15 directed mutagenesis and the like. In one embodiment, a nucleic acid fragment of the invention comprises the full length coding sequence of a mutant delta-12 or mutant delta-15 fatty acid desaturase.

A mutation in a nucleic acid fragment of the  
20 invention may be in any portion of the coding sequence that renders the resulting gene product non-functional. Suitable types of mutations include, without limitation, insertions of nucleotides, deletions of nucleotides, or transitions and transversions in the wild-type coding  
25 sequence. Such mutations result in insertions of one or more amino acids, deletions of one or more amino acids, and non-conservative amino acid substitutions in the corresponding gene product. In some embodiments, the sequence of a nucleic acid fragment may comprise more  
30 than one mutation or more than one type of mutation.

Insertion or deletion of amino acids in a coding sequence may, for example, disrupt the conformation of essential alpha-helical or beta-pleated sheet regions of the resulting gene product. Amino acid insertions or  
35 deletions may also disrupt binding or catalytic sites

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important for gene product activity. It is known in the art that the insertion or deletion of a larger number of contiguous amino acids is more likely to render the gene product non-functional, compared to a smaller number of  
5 inserted or deleted amino acids.

Non-conservative amino acid substitutions may replace an amino acid of one class with an amino acid of a different class. Non-conservative substitutions may make a substantial change in the charge or hydrophobicity  
10 of the gene product. Non-conservative amino acid substitutions may also make a substantial change in the bulk of the residue side chain, e.g., substituting an alanyl residue for a isoleucyl residue.

Examples of non-conservative substitutions include  
15 the substitution of a basic amino acid for a non-polar amino acid, or a polar amino acid for an acidic amino acid. Because there are only 20 amino acids encoded in a gene, substitutions that result in a non-functional gene product may be determined by routine experimentation,  
20 incorporating amino acids of a different class in the region of the gene product targeted for mutation.

Preferred mutations are in a region of the nucleic acid having an amino acid sequence motif that is conserved among delta-12 fatty acid desaturases or delta-  
25 15 fatty acid desaturases, such as a His-Xaa-Xaa-Xaa-His motif (Tables 1-3). An example of a suitable region has a conserved HECGH motif that is found, for example, in nucleotides corresponding to amino acids 105 to 109 of the *Arabidopsis* and *Brassica* delta-12 desaturase  
30 sequences, in nucleotides corresponding to amino acids 101 to 105 of the soybean delta-12 desaturase sequence and in nucleotides corresponding to amino acids 111 to 115 of the maize delta-12 desaturase sequence. See e.g., WO 94/115116; Okuley et al., Plant Cell 6:147-158 (1994).  
35 The one letter amino acid designations used herein are

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described in Alberts, B. et al., Molecular Biology of the Cell, 3rd edition, Garland Publishing, New York, 1994. Amino acids flanking this motif are also highly conserved among delta-12 and delta-15 desaturases and are also  
5 suitable candidates for mutations in fragments of the invention. An illustrative embodiment of a mutation in a nucleic acid fragment of the invention is a Glu to Lys substitution in the HECGH motif of a *Brassica* microsomal delta-12 desaturase sequence, either the D form or the F  
10 form. This mutation results in the sequence HECGH being changed to HKCGH as seen by comparing SEQ ID NO:2 (wild-type D form) to SEQ ID NO:4 (mutant D form).

A similar motif may be found at amino acids 101 to 105 of the *Arabidopsis* microsomal delta-15 fatty acid  
15 desaturase, as well as in the corresponding rape and soybean desaturases (Table 5). See, e.g., WO 93/11245; Arondel, V. et al., Science, 258:1153-1155 (1992); Yadav, N. et al., Plant Physiol., 103:467-476 (1993). Plastid delta-15 fatty acids have a similar motif (Table 5).

20 Among the types of mutations in an HECGH motif that render the resulting gene product non-functional are non-conservative substitutions. An illustrative example of a non-conservative substitution is substitution of a glycine residue for either the first or second histidine.  
25 Such a substitution replaces a polar residue (histidine) with a non-polar residue (glycine). Another type of mutation that renders the resulting gene product non-functional is an insertion mutation, e.g., insertion of a glycine between the cystine and glutamic acid residues in  
30 the HECGH motif.

Other regions having suitable conserved amino acid motifs include the HRRHH motif shown in Table 2, the HRTTH motif shown in Table 6 and the HVAHH motif shown in Table 3. See, e.g., WO 94/115116; Hitz, W. et al., Plant



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Physiol., 105:635-641 (1994); Okuley, J., et al., supra; and Yadav, N. et al., supra.

Another region suitable for a mutation in a delta-12 desaturase sequence contains the motif KYLNNP at 5 nucleotides corresponding to amino acids 171 to 175 of the *Brassica* desaturase sequence. An illustrative example of a mutation in this region is a Leu to His substitution, resulting in the amino acid sequence (Table 4) KYHNN (Compare wild-type SEQ ID NO:6 to mutant SEQ ID 10 NO:8).

**TABLE 1**

Alignment of Amino Acid Sequences from Microsomal  
Delta-12 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
15	<i>Arabidopsis thaliana</i>	100-129	IWVIAHECGH HAFSDYQWLD DTVGLIFHSF
	<i>Glycine max</i>	96-125	VWVIAHECGH HAFSKYQWVD DVVGLTLHST
	<i>Zea mays</i>	106-135	VWVIAHECGH HAFSDYSLLD DVVGLVLHSS
	<i>Ricinus communis</i> <sup>a</sup>	1- 29	WVMAHDCGH HAFSDYQLLD DVVGLILHSC
	<i>Brassica napus D</i>	100-128	VWVIAHECGH HAFSDYQWLD DTVGLIFHS
20	<i>Brassica napus F</i>	100-128	VWVIAHECGH HAFSDYQWLD DTVGLIFHS

<sup>a</sup> from plasmid pRF2-1C

**TABLE 2**

Alignment of Amino Acid Sequences from Microsomal  
Delta-12 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
25	<i>Arabidopsis thaliana</i>	130-158	LLVPYFSWKY SHRRHHSNTG SLERDEVFV
	<i>Glycine max</i>	126-154	LLVPYFSWKI SHRRHHSNTG SLDRDEVFV
	<i>Zea mays</i>	136-164	LMVPYFSWKY SHRRHHSNTG SLERDEVFV
	<i>Ricinus communis</i> <sup>a</sup>	30- 58	LLVPYFSWKH SHRRHHSNTG SLERDEVFV
30	<i>Brassica napus D</i>	130-158	LLVPYFSWKY SHRSHHSNTG SLERDEVFV
	<i>Brassica napus F</i>	130-158	LLVPYFSWKY SHRRHHSNTG SLERDEVFV

<sup>a</sup> from plasmid pRF2-1C

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**TABLE 3**

Alignment of Amino Acid Sequences from Microsomal  
Delta-12 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
5	<i>Arabidopsis thaliana</i>	298-333	DRDYGILNKV FHNITDTHVA HHLFSTMPHY NAMEAT
	<i>Glycine max</i>	294-329	DRDYGILNKV FHNITDTHVA HHLFSTMPHY HAMEAT
	<i>Zea mays</i>	305-340	DRDYGILNRV FHNITDTHVA HHLFSTMPHY HAMEAT
	<i>Ricinus communis</i> *	198-224	DRDYGILNKV FHNITDTQVA HHLF TMP
	<i>Brassica napus D</i>	299-334	DRDYGILNKV FHNITDTHVA HHPFSTMPHY HAMEAT
10	<i>Brassica napus F</i>	299-334	DRDYGILNKV FHNITDTHVA HHLFSTMPHY HAMEAT

\* from plasmid pRF2-1C

**TABLE 4**

Alignment of Conserved Amino Acids from Microsomal  
Delta-12 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
15	<i>Arabidopsis thaliana</i>	165-180	IKWYGKYLNN PLGRIM
	<i>Glycine max</i>	161-176	VAWFSLYLNN PLGRAV
	<i>Zea mays</i>	172-187	PWYTPYVYNN PVGRVV
	<i>Ricinus communis</i> *	65- 80	IRWYSKYLNN PPGRIM
20	<i>Brassica napus D</i>	165-180	IKWYGKYLNN PLGRTV
	<i>Brassica napus F</i>	165-180	IKWYGKYLNN PLGRTV

\* from plasmid pRF2-1C

**TABLE 5**

Alignment of Conserved Amino Acids from Plastid and Microsomal  
Delta-15 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
25	<i>Arabidopsis thaliana</i> *	156-177	WALFVLGHD CGHGSFSNDP KLN
	<i>Brassica napus</i> *	114-135	WALFVLGHD CGHGSFSNDP RLN
	<i>Glycine max</i> *	164-185	WALFVLGHD CGHGSFSNNS KLN
30	<i>Arabidopsis thaliana</i>	94-115	WALFVLGHD CGHGSFSDIP LLN
	<i>Brassica napus</i>	87-109	WALFVLGHD CGHGSFSNDP RLN
	<i>Glycine max</i>	93-114	WALFVLGHD CGHGSFSDSP PLN

\* Plastid sequences

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TABLE 6

Alignment of Conserved Amino Acids from Plastid and Microsomal  
Delta-15 Fatty Acid Desaturases

	<u>Species</u>	<u>Position</u>	<u>Amino Acid Sequence</u>
5	<i>A. thaliana</i> <sup>a</sup>	188-216	ILVPYHGWRI SHRTHQNHG HVENDESWH
	<i>B. napus</i> <sup>a</sup>	146-174	ILVPYHGWRI SHRTHQNHG HVENDESWH
	<i>Glycine max</i> <sup>a</sup>	196-224	ILVPYHGWRI SHRTHQNHG HAENDESWH
	<i>A. thaliana</i>	126-154	ILVPYHGWRI SHRTHQNHG HVENDESWV
	<i>Brassica napus</i>	117-145	ILVPYHGWRI SHRTHQNHG HVENDESWV
10	<i>Glycine max</i>	125-153	ILVPYHGWRI SHRTHQNHG HIEKDESWV

<sup>a</sup> Plastid sequences

The conservation of amino acid motifs and their relative positions indicates that regions of a delta-12 or delta-15 fatty acid desaturase that can be mutated in one species to generate a non-functional desaturase can be mutated in the corresponding region from other species to generate a non-functional 12-DES or 15-DES gene product in that species.

Mutations in any of the regions of Tables 1-6 are specifically included within the scope of the invention, provided that such mutation (or mutations) renders the resulting desaturase gene product non-functional, as discussed hereinabove.

A nucleic acid fragment containing a mutant sequence can be generated by techniques known to the skilled artisan. Such techniques include, without limitation, site-directed mutagenesis of wild-type sequences and direct synthesis using automated DNA synthesizers.

A nucleic acid fragment containing a mutant sequence can also be generated by mutagenesis of plant seeds or regenerable plant tissue by, e.g., ethyl methane sulfonate, X-rays or other mutagens. With mutagenesis, mutant plants having the desired fatty acid phenotype in seeds are identified by known techniques and a nucleic acid fragment containing the desired mutation is isolated from genomic DNA or RNA of the mutant line. The site of

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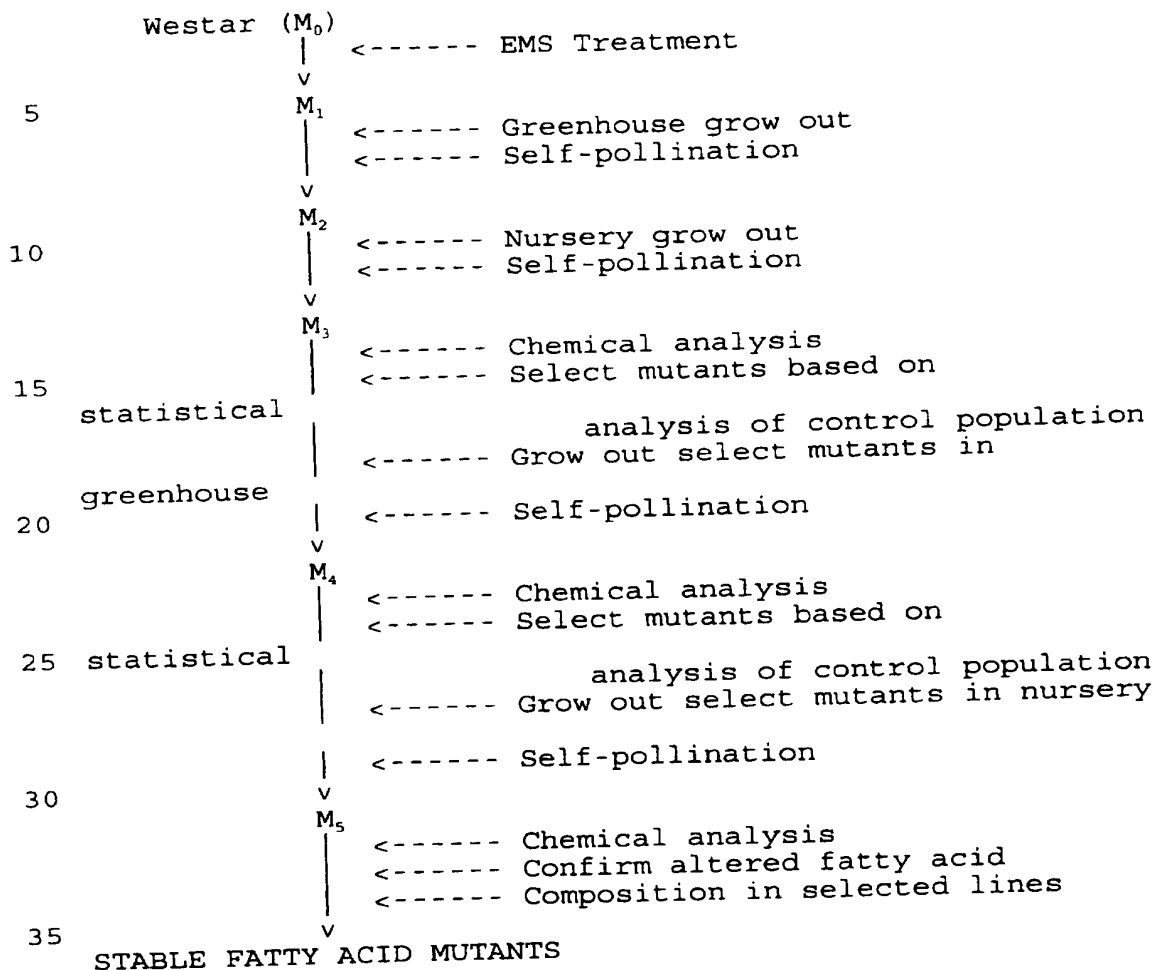
the specific mutation is then determined by sequencing the coding region of the 12-DES or 15-DES gene.

Alternatively, labeled nucleic acid probes that are specific for desired mutational events can be used to  
5 rapidly screen a mutagenized population.

Seeds of Westar, a Canadian (*Brassica napus*) spring canola variety, were subjected to chemical mutagenesis. Mutagenized seeds were planted in the greenhouse and the plants were self-pollinated. The  
10 progeny plants were individually analyzed for fatty acid composition, and regrown either in the greenhouse or in the field. After four successive generations of self-pollinations, followed by chemical analysis of the seed oil at each cycle, several lines were shown to carry  
15 stably inherited mutations in specific fatty acid components, including reduced palmitic acid ( $C_{16:0}$ ), increased palmitic acid, reduced stearic acid ( $C_{18:0}$ ), increased oleic acid ( $C_{18:1}$ ), reduced linoleic acid ( $C_{18:2}$ ) and reduced linolenic acid ( $C_{18:3}$ ), in the seed oil.

20 The general experimental scheme for developing lines with stable fatty acid mutations is shown in Scheme I hereinafter.

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SCHEME I

Westar seeds (M<sub>0</sub>) were mutagenized with ethylmethanesulfonate (EMS). Westar is a registered Canadian spring variety with canola quality. The fatty acid composition of field-grown Westar, 3.9% C<sub>16:0</sub>, 1.9% C<sub>18:0</sub>, 67.5% C<sub>18:1</sub>, 17.6% C<sub>18:2</sub>, 7.4% C<sub>18:3</sub>, <2% C<sub>20:1</sub> + C<sub>22:1</sub>, has remained stable under commercial production, with  $\pm$  10% deviation, since 1982. The disclosed method may be applied to all oilseed *Brassica* species, and to both Spring and Winter maturing types within each species. Physical mutagens, including but not limited to X-rays,

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UV rays, and other physical treatments which cause chromosome damage, and other chemical mutagens, including but not limited to ethidium bromide, nitrosoguanidine, diepoxybutane etc. may also be used to induce mutations.

5 The mutagenesis treatment may also be applied to other stages of plant development, including but not limited to cell cultures, embryos, microspores and shoot apices. The  $M_1$  seeds were planted in the greenhouse and  $M_1$  plants were individually self-pollinated.

10  $M_2$  seed was harvested from the greenhouse and planted in the field in a plant-to-row design. Each plot contained six rows, and five  $M_2$  lines were planted in each plot. Every other plot contained a row of non-mutagenized Westar as a control. Based on gas  
15 chromatographic analysis of  $M_2$  seed, those lines which had altered fatty acid composition were self-pollinated and individually harvested.

$M_3$  seeds were evaluated for mutations on the basis of a Z-distribution. An extremely stringent 1 in 10,000  
20 rejection rate was employed to establish statistical thresholds to distinguish mutation events from existing variation. Mean and standard deviation values were determined from the non-mutagenized Westar control population in the field. The upper and lower statistical  
25 thresholds for each fatty acid were determined from the mean value of the population  $\pm$  the standard deviation, multiplied by the Z-distribution. Based on a population size of 10,000, the confidence interval is 99.99%.

Seeds ( $M_3$ ) from those  $M_2$  lines which exceeded  
30 either the upper or lower statistical thresholds were replanted in the greenhouse and self-pollinated. This planting also included Westar controls. The  $M_4$  seed was re-analyzed using new statistical thresholds established with a new control population. Those  $M_4$  lines which  
35 exceeded the new statistical thresholds for selected

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fatty acid compositions were advanced to the nursery. Following self-pollination,  $M_5$  seed from the field were re-analyzed once again for fatty acid composition. Those lines which remained stable for the selected fatty acids  
5 were considered stable mutations.

"Stable mutations" as used herein are defined as  $M_5$  or more advanced lines which maintain a selected altered fatty acid profile for a minimum of three generations, including a minimum of two generations under  
10 field conditions, and exceeding established statistical thresholds for a minimum of two generations, as determined by gas chromatographic analysis of a minimum of 10 randomly selected seeds bulked together. Alternatively, stability may be measured in the same way  
15 by comparing to subsequent generations. In subsequent generations, stability is defined as having similar fatty acid profiles in the seed as that of the prior or subsequent generation when grown under substantially similar conditions.

20 The amount of variability for fatty acid content in a seed population is quite significant when single seeds are analyzed. Randomly selected single seeds and a ten seed bulk sample of a commercial variety were compared. Significant variation among the single seeds  
25 was detected (Table A). The half-seed technique (Downey, R.K. and B.L. Harvey, Can. J. Plant Sci., 43:271 [1963]) in which one cotyledon of the germinating seed is analyzed for fatty acid composition and the remaining embryo grown into a plant has been very useful to plant  
30 breeding work to select individuals in a population for further generation analysis. The large variation seen in the single seed analysis (Table A) is reflected in the half-seed technique.

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**TABLE A****Single Seed Analysis for Fatty Acid Composition<sup>1</sup>**

	SAMPLE	16:0	16:1	18:0	18:1	18:2	18:3	20:0	20:1	22:0	22:1
	Bulk	3.2	0.4	1.8	20.7	13.7	9.8	0.8	11.2	0.4	32.2
5	1	2.8	0.2	1.1	14.6	14.6	11.1	0.8	9.8	0.7	38.2
	2	3.3	0.2	1.3	13.1	14.4	11.7	0.9	10.5	0.7	37.0
	3	3.0	--	1.2	12.7	15.3	10.6	0.8	7.3	0.7	43.2
	4	2.8	0.2	1.1	16.7	13.2	9.1	0.8	11.2	0.4	38.9
	5	3.0	--	1.8	15.2	13.3	8.4	1.3	8.7	0.9	42.3
10	6	3.1	--	1.3	14.4	14.6	10.3	1.0	10.9	0.8	39.3
	7	2.6	--	1.2	15.7	13.8	9.9	0.9	12.2	0.5	37.0
	8	3.1	--	1.1	16.2	13.4	10.6	0.6	9.2	0.8	41.4
	9	2.7	0.1	1.0	13.5	11.2	11.3	0.8	6.2	0.7	46.9
	10	3.4	0.2	1.4	13.9	17.5	10.8	1.1	10.0	0.9	36.2
15	11	2.8	0.2	1.2	12.7	12.9	10.3	1.0	7.9	0.9	43.3
	12	2.3	0.1	1.6	20.7	14.8	6.5	1.1	12.5	0.8	34.5
	13	2.6	0.2	1.3	21.0	11.4	7.6	1.0	11.6	0.6	36.7
	14	2.6	0.1	1.2	14.7	13.2	9.4	0.9	10.1	0.8	40.8
	15	2.9	0.2	1.4	16.6	15.1	11.2	0.7	9.1	0.3	36.1
20	16	3.0	0.2	1.1	12.4	13.7	10.4	0.9	8.7	0.8	42.7
	17	2.9	0.1	1.1	21.1	12.3	7.1	0.8	12.4	0.5	36.8
	18	3.1	0.1	1.2	13.7	13.1	10.4	1.0	8.8	0.7	41.6
	19	2.7	0.1	1.0	11.1	13.4	11.7	0.8	7.9	0.8	43.5
	20	2.3	0.2	0.2	18.2	13.9	8.2	0.9	10.3	0.8	38.2
25	Average	2.8	0.2	1.2	15.4	13.8	9.8	0.9	9.8	0.7	39.7
	Minimum	2.3	0.1	0.2	11.1	11.2	6.5	0.6	6.2	0.3	34.5
	Maximum	3.4	0.2	1.8	21.1	17.5	11.7	1.3	12.5	0.9	46.9
	Range	1.1	0.1	1.6	9.9	6.3	5.3	0.7	6.4	0.6	12.4

Values expressed as percent of total oil

30 Plant breeders using the half-seed technique have found it unreliable in selecting stable genetically controlled fatty acid mutations (Stefanson, B.R., In; High and Low Erucic Acid Rapeseed Oils, Ed. N.T. Kenthies, Academic Press, Inc., Canada (1983) pp. 145-  
35 159). Although valuable in selecting individuals from a population, the selected traits are not always transmitted to subsequent generations (Rakow, G. and McGregor, D.I., J. Amer. Oil Chem. Soc. (1973) 50:400-403. To determine the genetic stability of the selected  
40 plants several self-pollinated generations are required (Robelen, G. In: Biotechnology for the Oils and Fats Industry, Ed. C. Ratledge, P. Dawson and J. Rattray,



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American Oil Chemists Society (1984) pp. 97-105) with chemical analysis of a bulk seed sample.

Mutation breeding has traditionally produced plants carrying, in addition to the trait of interest, multiple, deleterious traits, e.g., reduced plant vigor and reduced fertility. Such traits may indirectly affect fatty acid composition, producing an unstable mutation; and/or reduce yield, thereby reducing the commercial utility of the invention. To eliminate the occurrence of deleterious mutations and reduce the load of mutations carried by the plant a low mutagen dose was used in the seed treatments to create an LD30 population. This allowed for the rapid selection of single gene mutations for fatty acid traits in agronomic backgrounds which produce acceptable yields.

Other than changes in the fatty acid composition of the seed oil, the mutant lines described here have normal plant phenotype when grown under field conditions, and are commercially useful. "Commercial utility" is defined as having a yield, as measured by total pounds of seed or oil produced per acre, within 15% of the average yield of the starting ( $M_0$ ) canola variety grown in the same region. To be commercially useful, plant vigor and high fertility are such that the crop can be produced in this yield by farmers using conventional farming equipment, and the oil with altered fatty acid composition can be extracted using conventional crushing and extraction equipment.

The seeds of several different fatty acid lines have been deposited with the American Type Culture Collection and have the following accession numbers.

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	<u>Line</u>	<u>Accession No.</u>	<u>Deposit Date</u>
	A129.5	40811	May 25, 1990
	A133.1	40812	May 25, 1990
	A144.1	40813	May 25, 1990
5	A200.7	40816	May 31, 1990
	M3032.1	75021	June 7, 1991
	M3094.4	75023	June 7, 1991
	M3052.6	75024	June 7, 1991
	M3007.4	75022	June 7, 1991
10	M3062.8	75025	June 7, 1991
	M3028.10	75026	June 7, 1991
	IMC130	75446	April 16, 1993

In some plant species or varieties more than one form of endogenous microsomal delta-12 desaturase may be found. In amphidiploids, each form may be derived from one of the parent genomes making up the species under consideration. Plants with mutations in both forms have a fatty acid profile that differs from plants with a mutation in only one form. An example of such a plant is *Brassica napus* line Q508, a doubly-mutagenized line containing a mutant D-form of delta-12 desaturase (SEQ ID NO:1) and a mutant F-form of delta-12 desaturase (SEQ ID NO:5).

Preferred host or recipient organisms for introduction of a nucleic acid fragment of the invention are the oil-producing species, such as soybean (*Glycine max*), rapeseed (e.g., *Brassica napus*, *B. rapa* and *B. juncea*), sunflower (*Helianthus annuus*), castor bean (*Ricinus communis*), corn (*Zea mays*), and safflower (*Carthamus tinctorius*).

Plants according to the invention preferably contain an altered fatty acid profile. For example, oil obtained from seeds of such plants may have from about 69 to about 90% oleic acid, based on the total fatty acid composition of the seed. Such oil preferably has from about 74 to about 90% oleic acid, more preferably from about 80 to about 90% oleic acid. In some embodiments, oil obtained from seeds produced by plants of the

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invention may have from about 2.0% to about 5.0% saturated fatty acids, based on total fatty acid composition of the seeds. In some embodiments, oil obtained from seeds of the invention may have from about 5 1.0% to about 14.0% linoleic acid, or from about 0.5% to about 10.0%  $\alpha$ -linolenic acid.

In one embodiment of the claimed invention, a plant contains both a 12-DES mutation and a 15-DES mutation. Such plants can have a fatty acid composition 10 comprising very high oleic acid and very low alpha-linolenic acid levels. Mutations in 12-DES and 15-DES may be combined in a plant by making a genetic cross between 12-DES and 15-DES single mutant lines. A plant having a mutation in delta-12 fatty acid desaturase is 15 crossed or mated with a second plant having a mutation in delta-15 fatty acid desaturase. Seeds produced from the cross are planted and the resulting plants are selfed in order to obtain progeny seeds. These progeny seeds are then screened in order to identify those seeds carrying 20 both mutant genes.

Alternatively, a line possessing either a 12-DES or a 15-DES mutation can be subjected to mutagenesis to generate a plant or plant line having mutations in both 12-DES and 15-DES. For example, the IMC 129 line has a 25 mutation in the coding region (Glu<sub>106</sub> to Lys<sub>106</sub>) of the D form of the microsomal delta-12 desaturase structural gene. Cells (e.g., seeds) of this line can be mutagenized to induce a mutation in a 15-DES gene, resulting in a plant or plant line carrying a mutation in 30 a delta-12 fatty acid desaturase gene and a mutation in a delta-15 fatty acid desaturase gene.

Progeny includes descendants of a particular plant or plant line, e.g., seeds developed on an instant plant. Progeny of an instant plant include seeds formed on F<sub>1</sub>.

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F<sub>2</sub>, F<sub>3</sub>, and subsequent generation plants, or seeds formed on BC<sub>1</sub>, BC<sub>2</sub>, BC<sub>3</sub> and subsequent generation plants.

Those seeds having an altered fatty acid composition may be identified by techniques known to the skilled artisan, e.g., gas-liquid chromatography (GLC) analysis of a bulked seed sample or of a single half-seed. Half-seed analysis is well known in the art to be useful because the viability of the embryo is maintained and thus those seeds having a desired fatty acid profile may be planted to from the next generation. However, half-seed analysis is also known to be an inaccurate representation of genotype of the seed being analyzed. Bulk seed analysis typically yields a more accurate representation of the fatty acid profile of a given genotype.

The nucleic acid fragments of the invention can be used as markers in plant genetic mapping and plant breeding programs. Such markers may include restriction fragment length polymorphism (RFLP), random amplification polymorphism detection (RAPD), polymerase chain reaction (PCR) or self-sustained sequence replication (3SR) markers, for example. Marker-assisted breeding techniques may be used to identify and follow a desired fatty acid composition during the breeding process. Marker-assisted breeding techniques may be used in addition to, or as an alternative to, other sorts of identification techniques. An example of marker-assisted breeding is the use of PCR primers that specifically amplify a sequence containing a desired mutation in 12-DES or 15-DES.

Methods according to the invention are useful in that the resulting plants and plant lines have desirable seed fatty acid compositions as well as superior agronomic properties compared to known lines having altered seed fatty acid composition. Superior agronomic

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characteristics include, for example, increased seed germination percentage, increased seedling vigor, increased resistance to seedling fungal diseases (damping off, root rot and the like), increased yield, and  
5 improved standability.

While the invention is susceptible to various modifications and alternative forms, certain specific embodiments thereof are described in the general methods and examples set forth below. For example the invention  
10 may be applied to all *Brassica* species, including *B. rapa*, *B. juncea*, and *B. hirta*, to produce substantially similar results. It should be understood, however, that these examples are not intended to limit the invention to the particular forms disclosed but, instead the invention  
15 is to cover all modifications, equivalents and alternatives falling within the scope of the invention. This includes the use of somaclonal variation; physical or chemical mutagenesis of plant parts; anther, microspore or ovary culture followed by chromosome  
20 doubling; or self- or cross-pollination to transmit the fatty acid trait, alone or in combination with other traits, to develop new *Brassica* lines.

#### EXAMPLE 1

##### Selection of Low FDA Saturates

25 Prior to mutagenesis, 30,000 seeds of *B. napus* cv. Westar seeds were preimbibed in 300-seed lots for two hours on wet filter paper to soften the seed coat. The preimbibed seeds were placed in 80 mM ethylmethanesulfonate (EMS) for four hours. Following  
30 mutagenesis, the seeds were rinsed three times in distilled water. The seeds were sown in 48-well flats containing Pro-Mix. Sixty-eight percent of the mutagenized seed germinated. The plants were maintained at 25°C/15°C, 14/10 hr day/night conditions in the

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greenhouse. At flowering, each plant was individually self-pollinated.

$M_2$  seed from individual plants were individually catalogued and stored, approximately 15,000  $M_2$  lines was  
5 planted in a summer nursery in Carman, Manitoba. The seed from each selfed plant were planted in 3-meter rows with 6-inch row spacing. Westar was planted as the check variety. Selected lines in the field were selfed by bagging the main raceme of each plant. At maturity, the  
10 selfed plants were individually harvested and seeds were catalogued and stored to ensure that the source of the seed was known.

Self-pollinated  $M_3$  seed and Westar controls were analyzed in 10-seed bulk samples for fatty acid  
15 composition via gas chromatography. Statistical thresholds for each fatty acid component were established using a Z-distribution with a stringency level of 1 in 10,000. The selected  $M_3$  seeds were planted in the greenhouse along with Westar controls. The seed was sown  
20 in 4-inch pots containing Pro-Mix soil and the plants were maintained at 25°C/15°C, 14/10 hr day/night cycle in the greenhouse. At flowering, the terminal raceme was self-pollinated by bagging. At maturity, selfed  $M_4$  seed was individually harvested from each plant, labelled, and  
25 stored to ensure that the source of the seed was known.

The  $M_4$  seed was analyzed in 10-seed bulk samples. Statistical thresholds for each fatty acid component were established from 259 control samples using a Z-distribution of 1 in 800. Selected  $M_4$  lines were planted  
30 in a field trial in Carman, Manitoba in 3-meter rows with 6-inch spacing. Ten  $M_4$  plants in each row were bagged for self-pollination. At maturity, the selfed plants were individually harvested and the open pollinated plants in the row were bulk harvested. The  $M_5$  seed from single

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plant selections was analyzed in 10-seed bulk samples and the bulk row harvest in 50-seed bulk samples.

Selected  $M_5$  lines were planted in the greenhouse along with Westar controls. The seed was grown as previously described. At flowering the terminal raceme was self-pollinated by bagging. At maturity, selfed  $M_5$  seed was individually harvested from each plant and analyzed in 10-seed bulk samples for fatty acid composition.

Selected  $M_6$  lines were entered into field trials in Eastern Idaho. The four trial locations were selected for the wide variability in growing conditions. The locations included Burley, Tetonia, Lamont and Shelley (Table I). The lines were planted in four 3-meter rows with an 8-inch spacing, each plot was replicated four times. The planting design was determined using a Randomized Complete Block Design. The commercial cultivar Westar was used as a check cultivar. At maturity the plots were harvested to determine yield. Yield of the entries in the trial was determined by taking the statistical average of the four replications. The Least Significant Difference Test was used to rank the entries in the randomized complete block design.

**TABLE I**

**Trial Locations for Selected Fatty Acid Mutants**

<u>LOCATION</u>	<u>SITE CHARACTERIZATIONS</u>
BURLEY	Irrigated. Long season. High temperatures during flowering.
TETONIA	Dryland. Short season. Cool temperatures.
LAMONT	Dryland. Short season. Cool temperatures.
SHELLEY	Irrigated. Medium season. High temperatures during flowering.

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To determine the fatty acid profile of entries, plants in each plot were bagged for self-pollination. The M<sub>1</sub> seed from single plants was analyzed for fatty acids in ten-seed bulk samples.

5 To determine the genetic relationships of the selected fatty acid mutants crosses were made. Flowers of M<sub>6</sub> or later generation mutations were used in crossing. F<sub>1</sub> seed was harvested and analyzed for fatty acid composition to determine the mode of gene action. The F<sub>1</sub> progeny were planted in the greenhouse. The resulting plants were self-pollinated, the F<sub>2</sub> seed harvested and analyzed for fatty acid composition for allelism studies. The F<sub>2</sub> seed and parent line seed was planted in the greenhouse, individual plants were self-pollinated. The F<sub>3</sub> seed of individual plants was tested for fatty acid composition using 10-seed bulk samples as described previously.

In the analysis of some genetic relationships dihaploid populations were made from the microspores of the F<sub>1</sub> hybrids. Self-pollinated seed from dihaploid plants were analyzed for fatty acid analysis using methods described previously.

For chemical analysis, 10-seed bulk samples were hand ground with a glass rod in a 15-mL polypropylene tube and extracted in 1.2 mL 0.25 N KOH in 1:1 ether/methanol. The sample was vortexed for 30 sec. and heated for 60 sec. in a 60°C water bath. Four mL of saturated NaCl and 2.4 mL of iso-octane were added, and the mixture was vortexed again. After phase separation, 600 µL of the upper organic phase were pipetted into individual vials and stored under nitrogen at -5°C. One µL samples were injected into a Supelco SP-2330 fused silica capillary column (0.25 mm ID, 30 M length, 0.20 µm df).



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The gas chromatograph was set at 180°C for 5.5 minutes, then programmed for a 2°C/minute increase to 212°C, and held at this temperature for 1.5 minutes. Total run time was 23 minutes. Chromatography settings were: Column head pressure - 15 psi, Column flow (He) - 0.7 mL/min., Auxiliary and Column flow - 33 mL/min., Hydrogen flow - 33 mL/min., Air flow - 400 mL/min., Injector temperature - 250°C, Detector temperature - 300°C, Split vent - 1/15.

Table II describes the upper and lower statistical thresholds for each fatty acid of interest.

**TABLE II**

Statistical Thresholds for Specific Fatty Acids  
Derived from Control Westar Plantings

Genotype	Percent Fatty Acids					
	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats*
M <sub>3</sub> Generation (1 in 10,000 rejection rate)						
Lower	3.3	1.4	--	13.2	5.3	6.0
Upper	4.3	2.5	71.0	21.6	9.9	8.3
M <sub>4</sub> Generation (1 in 800 rejection rate)						
Lower	3.6	0.8	--	12.2	3.2	5.3
Upper	6.3	3.1	76.0	32.4	9.9	11.2
M <sub>5</sub> Generation (1 in 755 rejection rate)						
Lower	2.7	0.9	--	9.6	2.6	4.5
Upper	5.7	2.7	80.3	26.7	9.6	10.0

\*Sats=Total Saturate Content

At the M<sub>3</sub> generation, twelve lines exceeded the lower statistical threshold for palmitic acid ( $\leq 3.3\%$ ). Line W13097.4 had 3.1% palmitic acid and an FDA saturate content of 4.5%. After a cycle in the greenhouse, M<sub>4</sub> seed

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from line W13097.4 (designated line A144) was analyzed. Line W13097.4.1(A144.1) had 3.1% C<sub>16:0</sub>, exceeding the lower statistical threshold of 3.6%. The FDA saturate content for A144.1 was 4.5%. The fatty acid compositions for the 5 M<sub>3</sub>, M<sub>4</sub> and M<sub>5</sub> generations of this family are summarized in Table III.

**TABLE III**

Fatty Acid Composition of a Low Palmitic Acid/Low FDA Saturate Canola Line Produced by Seed Mutagenesis

Genotype <sup>a</sup>	Percent Fatty Acids						
	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats <sup>b</sup>	Tot Sat <sup>c</sup>
Westar 7.0	3.9	1.9	67.5	17.6	7.4	5.9	
15 W13097.4 (M <sub>3</sub> )	3.1	1.4	63.9	18.6	9.5	4.5	5.6
W13097.4 (M <sub>4</sub> )	3.1	1.4	66.2	19.9	6.0	4.5	5.5
20 A144.1.9 (M <sub>5</sub> )	2.9	1.4	64.3	20.7	7.3	4.4	5.3

<sup>a</sup>Letter and numbers up to second decimal point indicate the plant line. Number after second decimal point indicates an individual plant.

25 <sup>b</sup>Sat=FDA Saturates

<sup>c</sup>Tot Sat=Total Saturate Content

The M<sub>5</sub> seed of ten self-pollinated A144.1 (ATCC 40813) plants averaged 3.1% palmitic acid and 4.7% FDA saturates. One selfed plant (A144.1.9) contained 2.9% palmitic acid and FDA saturates of 4.4%. Bulk seed analysis from open-pollinated (A144.1) plants at the M<sub>5</sub> generation averaged 3.1% palmitic acid and 4.7% FDA saturates. The fatty acid composition of the bulked and individual A144.1 lines are summarized in Table IV.

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**TABLE IV**

Fatty Acid Composition of A144  
Low Palmitic Acid/Low FDA Saturate Line

		Percent Fatty Acids						
5	Genotype <sup>a</sup>	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats <sup>b</sup>	Tot Sat <sup>c</sup>
Individually Self-Pollinated Plants								
	A144.1.1	3.2	1.6	64.4	20.5	7.0	4.8	5.9
	A144.1.2	3.0	1.5	67.4	18.6	6.3	4.5	5.7
10	A144.1.3	3.6	1.8	61.4	22.4	7.5	5.2	6.6
	A144.1.4	3.2	1.5	64.6	20.9	6.7	4.7	5.8
	A144.1.5	3.3	1.7	60.0	23.9	7.9	5.0	6.1
	A144.1.6	3.1	1.4	67.3	17.8	6.5	4.6	5.2
	A144.1.7	3.1	1.6	67.7	17.4	6.5	4.8	5.4
15	A144.1.8	3.1	1.8	66.9	18.7	6.1	4.9	5.4
	A144.1.9	2.9	1.4	64.3	20.7	7.3	4.4	5.3
	A144.1.10	3.1	1.5	62.5	20.4	7.7	4.6	5.6
Average of Individually Self-Pollinated Plants								
	A144.1.1-10	3.1	1.6	64.8	20.1	6.9	4.7	5.7
20	Bulk Analysis of Open-Pollinated Plants							
	A144.1B	3.1	1.6	64.8	19.4	7.8	4.7	5.7

<sup>a</sup>Letter and numbers up to second decimal point indicate the plant line. Number after second decimal point indicates an individual plant.

<sup>b</sup>Sat=FDA Saturates

<sup>c</sup>Tot Sat=Total Saturate Content

These reduced levels have remained stable to the M<sub>7</sub> generations in both greenhouse and field conditions.

30 These reduced levels have remained stable to the M<sub>7</sub> generation in multiple location field trails. Over all locations, the self-pollinated plants (A144) averaged 2.9% palmitic acid and FDA saturates of 4.6%. The fatty

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acid composition of the A144 lines for each Idaho location are summarized in Table V. In the multiple location replicated trial the yield of A144 was not significantly different in yield from the parent cultivar Westar. By means of seed mutagenesis, the level of saturated fatty acids of canola (*B. napus*) was reduced from 5.9% to 4.6%. The palmitic acid content was reduced from 3.9% to 2.9%.

**TABLE V**

10 Fatty Acid Composition of a Mutant Low Palmitic Acid/Low FDA Saturate Canola Line at Different Field Locations in Idaho

15	Trial Location	Percent Fatty Acids						
		C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats	Tot Sats
	Burley	2.9	1.3	62.3	20.6	10.3	4.2	5.0
	Tetonia	2.9	1.7	59.7	21.0	11.2	4.6	5.7
	Lamont	3.1	1.8	63.2	19.5	9.0	4.9	5.9
20	Shelley	2.8	1.9	64.5	18.8	8.8	4.7	5.9

To determine the genetic relationship of the palmitic acid mutation in A144 (C<sub>16:0</sub> - 3.0%, C<sub>18:0</sub> - 1.5%, C<sub>18:1</sub> - 67.4%, C<sub>18:2</sub> - 18.6%, C<sub>18:3</sub> - 6.3%) to other fatty acid mutations it was crossed to A129 a mutant high oleic acid (C<sub>16:0</sub> - 3.8%, C<sub>18:0</sub> - 2.3%, C<sub>18:1</sub> - 75.6%, C<sub>18:2</sub> - 9.5%, C<sub>18:3</sub> - 4.9%). Over 570 dihaploid progeny produced from the F<sub>1</sub> hybrid were harvested and analyzed for fatty acid composition. The results of the progeny analysis are summarized in Table VB. Independent segregation of the palmitic traits was observed which demonstrates that the genetic control of palmitic acid in A144 is different from the high oleic acid mutation in A129.

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TABLE VBGenetic Studies of Dihaploid Progeny of A144 X A129

		<u>Frequency</u>		
5	<u>Genotype</u>	<u>C<sub>16:0</sub> Content (%)</u>	<u>Observed</u>	<u>Expected</u>
	p-p-p2-p2-	3.0%	162	143
	p+p+p2-p2-	3.4%	236	286
	p+p+p2+p2+	3.8%	175	143

EXAMPLE 2

10 An additional low FDA saturate line, designated A149.3 (ATCC 40814), was also produced by the method of Example 1. A 50-seed bulk analysis of this line showed the following fatty acid composition: C<sub>16:0</sub> - 3.6%, C<sub>18:0</sub> - 1.4%, C<sub>18:1</sub> - 65.5%, C<sub>18:2</sub> - 18.3%, C<sub>18:3</sub> - 8.2%, FDA Sats - 5.0%, Total Sats - 5.9%. This line has also stably

15 maintained its mutant fatty acid composition to the M<sub>5</sub> generation. In a multiple location replicated trial the yield of A149 was not significantly different in yield from the parent cultivar Westar.

EXAMPLE 3

20 An additional low palmitic acid and low FDA saturate line, designated M3094.4 (ATCC 75023), was also produced by the method of Example 1. A 10-seed bulk analysis of this line showed the following fatty acid

25 composition: C<sub>16:0</sub> - 2.7%, C<sub>18:0</sub> - 1.6%, C<sub>18:1</sub> - 66.6%, C<sub>18:2</sub> - 20.0%, C<sub>18:3</sub> - 6.1%, C<sub>20:1</sub> - 1.4%, C<sub>22:1</sub> - 0.0%, FDA Saturate - 4.3%, Total Saturates - 5.2%. This line has stably

30 maintained its mutant fatty acid composition to the M<sub>5</sub> generation. In a single replicated trial the yield of M3094 was not significantly different in yield from the parent cultivar.

M3094.4 was crossed to A144, a low palmitic acid mutation (Example 1) for allelism studies. Fatty acid composition of the F<sub>2</sub> seed showed the two lines to be

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allelic. The mutational events in A144 and M3094, although different in origin, are in the same gene.

#### EXAMPLE 4

In the studies of Example 1, at the  $M_3$  generation, 5 470 lines exceed the upper statistical threshold for palmitic acid ( $\geq 4.3\%$ ). One  $M_3$  line, W14538.6, contained 9.2% palmitic acid. Selfed progenies of this line, since designated M3007.4 (ATCC 75022), continued to exceed to the upper statistical threshold for high palmitic acid at 10 both the  $M_4$  and  $M_5$  generations with palmitic acid levels of 11.7% and 9.1%, respectively. The fatty acid composition of this high palmitic acid mutant, which was stable to the  $M_7$  generation under both field and greenhouse conditions, is summarized in Table VI.

#### TABLE VI

Fatty Acid Composition of a High Palmitic Acid Canola Line Produced by Seed Mutagenesis

Genotype	Percent Fatty Acids					Sats*
	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	
20 Westar	3.9	1.9	67.5	17.6	7.4	7.0
W114538.6 ( $M_3$ )	8.6	1.6	56.4	20.3	9.5	10.2
M3007.2 ( $M_4$ )	11.7	2.1	57.2	18.2	5.1	13.9
25 M3007.4 ( $M_5$ )	9.1	1.4	63.3	13.7	5.5	12.7

\*Sats=Total Saturate Content

To determine the genetic relationship of the high 30 palmitic mutation in M3007.4 to the low palmitic mutation in A144 (Example 1) crosses were made. The  $F_2$  progeny were analyzed for fatty acid composition. The data presented in Table VIB shows the high palmitic group (C<sub>16:0</sub>

> 7.0%) makes up one-quarter of the total population analyzed. The high palmitic acid mutation was controlled by one single gene mutation.

TABLE VIB

5                    Genetic Studies of M3007 X A144

		<u>Frequency</u>	
<u>Genotype</u>		<u>C<sub>16:0</sub></u> <u>Content (%)</u>	
		<u>Observed</u>	<u>Expected</u>
10	p-p-/p-hp-	<7.0	151
	hp-hp-	>7.0	39
			142
			47

An additional  $M_3$  line, W4773.7, contained 4.5% palmitic acid. Selfed progenies of this line, since designated A200.7 (ATCC 40816), continued to exceed the upper statistical threshold for high palmitic acid in both the  $M_4$  and  $M_5$  generations with palmitic acid levels of 6.3% and 6.0%, respectively. The fatty acid composition of this high palmitic acid mutant, which was stable to the  $M_7$  generation under both field and greenhouse conditions, is summarized in Table VII.

**TABLE VII**

Fatty Acid Composition of a High Palmitic Acid Canola Line Produced by Seed Mutagenesis

		Percent Fatty Acids					
Genotype		C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats*
25	Westar	3.9	1.9	67.5	17.6	7.4	7.0
	W4773.7 (M <sub>3</sub> )	4.5	2.9	63.5	19.9	7.1	9.3
	M4773.7.7 (M <sub>4</sub> )	6.3	2.6	59.3	20.5	5.6	10.8
30	A200.7.7 (M <sub>5</sub> )	6.0	1.9	60.2	20.4	7.3	9.4
*Sats=Total Saturate Content							

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EXAMPLE 5Selection of Low Stearic Acid Canola Lines

In the studies of Example 1, at the  $M_3$  generation, 42 lines exceeded the lower statistical threshold for stearic acid (<1.4%). Line W14859.6 had 1.3% stearic acid. At the  $M_5$  generation, its selfed progeny (M3052.1) continued to fall within the lower statistical threshold for  $C_{18:0}$  with 0.8% stearic acid. The fatty acid composition of this low stearic acid mutant, which was stable under both field and greenhouse conditions is summarized in Table VIII. In a single location replicated yield trial M3052.1 was not significantly different in yield from the parent cultivar Westar.

TABLE VIII

Fatty Acid Composition of a Low Stearic Acid Canola Line Produced by Seed Mutagenesis

<u>Percent Fatty Acids</u>						
<u>Genotype</u>	<u><math>C_{16:0}</math></u>	<u><math>C_{18:0}</math></u>	<u><math>C_{18:1}</math></u>	<u><math>C_{18:2}</math></u>	<u><math>C_{18:3}</math></u>	<u>Sats</u>
Westar	3.9	1.9	67.5	17.6	7.4	5.9
20 W14859.6 ( $M_3$ )	5.3	1.3	56.1	23.7	9.6	7.5
M3052.1 ( $M_4$ )	4.9	0.9	58.9	22.7	9.3	5.8
25 M3052.6 ( $M_5$ )	4.4	0.8	62.1	21.2	7.9	5.2

To determine the genetic relationship of the low stearic acid mutation of M3052.1 to other fatty acid mutations it was crossed to the low palmitic acid mutation A144 (Example 1). Seed from over 300 dihaploid progeny were harvested and analyzed for fatty acid composition. The results are summarized in Table VIIIB. Independent segregation of the palmitic acid and stearic acid traits was observed. The low stearic acid mutation



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was genetically different from the low palmitic acid mutations found in A144 and M3094.

**TABLE VIIIB**  
**Genetic Studies of M3052 X A144**

5	Genotype	C <sub>16:0</sub> + C <sub>18:0</sub> Content (%)	Frequency	
			Observed	Expected
	p-p-s-s-	<4.9%	87	77
10	p-p-s-s-/p+p+s-s-	4.0%<X<5.6%	152	154
	p+p+s+s+	>5.6%	70	77

An additional M<sub>5</sub> line, M3051.10, contained 0.9% and 1.1% stearic acid in the greenhouse and field respectively. A ten-seed analysis of this line showed  
 15 the following fatty acid composition: C<sub>16:0</sub> - 3.9%, C<sub>18:0</sub> - 1.1%, C<sub>18:1</sub> - 61.7%, C<sub>18:2</sub> - 23.0%, C<sub>18:3</sub> - 7.6%, FDA saturates - 5.0%, Total Saturates - 5.8%. In a single location replicated yield trial M3051.10 was not significantly different in yield from the parent cultivar  
 20 Westar. M3051.10 was crossed to M3052.1 for allelism studies. Fatty acid composition of the F<sub>2</sub> seed showed the two lines to be allelic. The mutational events in M3051.10 and M3052.1 although different in origin were in the same gene.

25 An additional M<sub>5</sub> line, M3054.7, contained 1.0% and 1.3% stearic acid in the greenhouse and field respectively. A ten-seed analysis of this line showed the following fatty acid composition: C<sub>16:0</sub> - 4.0%, C<sub>18:0</sub> - 1.0%, C<sub>18:1</sub> - 66.5%, C<sub>18:2</sub> - 18.4%, C<sub>18:3</sub> - 7.2%, saturates -  
 30 5.0%, Total Saturates - 6.1%. In a single location replicated yield trial M3054.7 was not significantly different in yield from the parent cultivar Westar. M3054.7 was crossed to M3052.1 for allelism studies.

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Fatty acid composition of the F<sub>2</sub> seed showed the two lines to be allelic. The mutational events in M3054.7, M3051.10 and M3052.1 although different in origin were in the same gene.

5

EXAMPLE 6High Oleic Acid Canola Lines

In the studies of Example 1, at the M<sub>3</sub> generation, 31 lines exceeded the upper statistical threshold for oleic acid ( $\geq 71.0\%$ ). Line W7608.3 had 71.2% oleic acid.  
10 At the M<sub>4</sub> generation, its selfed progeny (W7608.3.5, since designated A129.5) continued to exceed the upper statistical threshold for C<sub>18:1</sub> with 78.8% oleic acid. M<sub>5</sub> seed of five self-pollinated plants of line A129.5 (ATCC 40811) averaged 75.0% oleic acid. A single plant  
15 selection, A129.5.3 had 75.6% oleic acid. The fatty acid composition of this high oleic acid mutant, which was stable under both field and greenhouse conditions to the M<sub>7</sub> generation, is summarized in Table IX. This line also stably maintained its mutant fatty acid composition to  
20 the M<sub>7</sub> generation in field trials in multiple locations. Over all locations the self-pollinated plants (A129) averaged 78.3% oleic acid. The fatty acid composition of the A129 for each Idaho trial location are summarized in Table X. In multiple location replicated yield trials,  
25 A129 was not significantly different in yield from the parent cultivar Westar.

The canola oil of A129, after commercial processing, was found to have superior oxidative stability compared to Westar when measured by the  
30 Accelerated Oxygen Method (AOM), American Oil Chemists' Society Official Method Cd 12-57 for fat stability; Active Oxygen Method (revised 1989). The AOM of Westar was 18 AOM hours and for A129 was 30 AOM hours.

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**TABLE IX**

Fatty Acid Composition of a High  
Oleic Acid Canola Line Produced by Seed Mutagenesis

Percent Fatty Acids							
5	Genotype	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats
	Westar	3.9	1.9	67.5	17.6	7.4	7.0
	W7608.3 (M <sub>3</sub> )	3.9	2.4	71.2	12.7	6.1	7.6
	W7608.3.5 (M <sub>4</sub> )	3.9	2.0	78.8	7.7	3.9	7.3
10	A129.5.3 (M <sub>5</sub> )	3.8	2.3	75.6	9.5	4.9	7.6

Sats=Total Saturate Content

**TABLE X**

15 Fatty Acid Composition of a Mutant High  
Oleic Acid Line at Different Field Locations in Idaho

Percent Fatty Acids						
Location	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats
Burley	3.3	2.1	77.5	8.1	6.0	6.5
20 Tetonia	3.5	3.4	77.8	6.5	4.7	8.5
Lamont	3.4	1.9	77.8	7.4	6.5	6.3
Shelley	3.3	2.6	80.0	5.7	4.5	7.7
Sats=Total Saturate Content						

Sats=Total Saturate Content

The genetic relationship of the high oleic acid  
25 mutation A129 to other oleic desaturases was demonstrated  
in crosses made to commercial canola cultivars and a low  
linolenic acid mutation. A129 was crossed to the  
commercial cultivar Global (C<sub>16:0</sub> - 4.5%, C<sub>18:0</sub> - 1.5%, C<sub>18:1</sub>  
- 62.9%, C<sub>18:2</sub> - 20.0%, C<sub>18:3</sub> - 7.3%). Approximately 200 F<sub>2</sub>  
30 individuals were analyzed for fatty acid composition.  
The results are summarized in Table XB. The segregation  
fit 1:2:1 ratio suggesting a single co-dominant gene

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controlled the inheritance of the high oleic acid phenotype.

**TABLE XB**  
**Genetic Studies of A129 X Global**

		Frequency	
		Observed	Expected
Genotype	C <sub>18:0</sub> Content (%)		
od-od-	77.3	43	47
od-od+	71.7	106	94
od+od+	66.1	49	47

A cross between A129 and IMC 01, a low linolenic acid variety (C<sub>16:0</sub> ~ 4.1%, C<sub>18:0</sub> ~ 1.9%, C<sub>18:1</sub> ~ 66.4%, C<sub>18:2</sub> ~ 18.1%, C<sub>18:3</sub> ~ 5.7%), was made to determine the inheritance of the oleic acid desaturase and linoleic acid desaturase. In the F<sub>1</sub> hybrids both the oleic acid and linoleic acid desaturase genes approached the mid-parent values indicating a co-dominant gene actions. Fatty acid analysis of the F<sub>2</sub> individuals confirmed a 1:2:1:2:4:2:1:2:1 segregation of two independent, co-dominant genes (Table XC). A line was selected from the cross of A129 and IMC01 and designated as IMC130 (ATCC deposit no. 75446) as described in U.S. Patent Application No. 08/425,108, incorporated herein by reference.

**TABLE XC**  
**Genetic Studies of A129 X IMC 01**

		Frequency	
		Observed	Expected
Genotype	Ratio		
od-od-ld-ld-	1	11	12
od-od-ld-ld+	2	30	24
od-od-ld+ld+	1	10	12
od-od+ld-ld-	2	25	24
od-od+ld-ld+	4	54	47
od-od+ld+ld+	2	18	24
od+od+ld-ld-	1	7	12
od+od+ld-ld+	2	25	24
od+od+ld+ld+	1	8	12

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An additional high oleic acid line, designated A128.3, was also produced by the disclosed method. A 50-seed bulk analysis of this line showed the following fatty acid composition:  $C_{16:0}$  - 3.5%,  $C_{18:0}$  - 1.8%,  $C_{18:1}$  - 77.3%,  $C_{18:2}$  - 9.0%,  $C_{18:3}$  - 5.6%, FDA Sats - 5.3%, Total Sats - 6.4%. This line also stably maintained its mutant fatty acid composition to the  $M_7$  generation. In multiple locations replicated yield trials, A128 was not significantly different in yield from the parent cultivar Westar.

A129 was crossed to A128.3 for allelism studies. Fatty acid composition of the  $F_2$  seed showed the two lines to be allelic. The mutational events in A129 and A128.3 although different in origin were in the same gene.

An additional high oleic acid line, designated M3028.-10 (ATCC 75026), was also produced by the disclosed method in Example 1. A 10-seed bulk analysis of this line showed the following fatty acid composition:  $C_{16:0}$  - 3.5%,  $C_{18:0}$  - 1.8%,  $C_{18:1}$  - 77.3%,  $C_{18:2}$  - 9.0%,  $C_{18:3}$  - 5.6%, FDA Saturates - 5.3%, Total Saturates - 6.4%. In a single location replicated yield trial M3028.10 was not significantly different in yield from the parent cultivar Westar.

#### EXAMPLE 7

##### Low Linoleic Acid Canola

In the studies of Example 1, at the  $M_3$  generation, 80 lines exceeded the lower statistical threshold for linoleic acid ( $\leq 13.2\%$ ). Line W12638.8 had 9.4% linoleic acid. At the  $M_4$  and  $M_5$  generations, its selfed progenies [W12638.8, since designated A133.1 (ATCC 40812)] continued to exceed the statistical threshold for low  $C_{18:2}$  with linoleic acid levels of 10.2% and 8.4%, respectively. The fatty acid composition of this low linoleic acid mutant, which was stable to the  $M_7$  generation under both field and greenhouse conditions, is

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summarized in Table XI. In multiple location replicated yield trials, A133 was not significantly different in yield from the parent cultivar Westar. An additional low linoleic acid line, designated M3062.8 (ATCC 75025), was also produced by the disclosed method. A 10-seed bulk analysis of this line showed the following fatty acid composition: C<sub>16:0</sub> - 3.8%, C<sub>18:0</sub> - 2.3%, C<sub>18:1</sub> - 77.1%, C<sub>18:2</sub> - 8.9%, C<sub>18:3</sub> - 4.3%, FDA Sats-6.1%. This line has also stably maintained its mutant fatty acid composition in the field and greenhouse.

**TABLE XI**

Fatty Acid Composition of a Low  
Linoleic Acid Canola Line Produced by Seed Mutagenesis

Percent Fatty Acids						
Genotype	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	Sats <sup>b</sup>
Westar	3.9	1.9	67.5	17.6	7.4	7.0
W12638.8 (M <sub>3</sub> )	3.9	2.3	75.0	9.4	6.1	7.5
W12638.8.1 (M <sub>4</sub> )	4.1	1.7	74.6	10.2	5.9	7.1
A133.1.8 (M <sub>5</sub> )	3.8	2.0	77.7	8.4	5.0	7.0

<sup>a</sup>Letter and numbers up to second decimal point indicate the plant line. Number after second decimal point indicates an individual plant.

<sup>b</sup>Sats=Total Saturate Content

**EXAMPLE 8**Low Linolenic and Linoleic Acid Canola

In the studies of Example 1, at the M<sub>3</sub> generation, 57 lines exceeded the lower statistical threshold for linolenic acid ( $\leq 5.3\%$ ). Line W14749.8 had 5.3% linolenic acid and 15.0% linoleic acid. At the M<sub>4</sub> and M<sub>5</sub>

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generations, its selfed progenies [W14749.8, since designated M3032 (ATCC 75021)] continued to exceed the statistical threshold for low  $C_{18:3}$  with linolenic acid levels of 2.7% and 2.3%, respectively, and for a low sum of linolenic and linoleic acids with totals of 11.8% and 12.5% respectively. The fatty acid composition of this low linolenic acid plus linoleic acid mutant, which was stable to the  $M_5$  generation under both field and greenhouse conditions, is summarized in Table XII. In a single location replicated yield trial M3032 was not significantly different in yield from the parent cultivar (Westar).

**TABLE XII**

Fatty Acid Composition of a Low  
Linolenic Acid Canola Line Produced by Seed Mutagenesis

Percent Fatty Acids

Genotype	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	Sats
Westar	3.9	1.9	67.5	17.6	7.4	7.0
W14749.8 ( $M_3$ )	4.0	2.5	69.4	15.0	5.3	6.5
M3032.8 ( $M_4$ )	3.9	2.4	77.9	9.1	2.7	6.4
M3032.1 ( $M_5$ )	3.5	2.8	80.0	10.2	2.3	6.5

Sats=Total Saturate Content

**EXAMPLE 9**

The high oleic acid mutation of A129 was introduced into different genetic backgrounds by crossing and selecting for fatty acid and agronomic characteristics. A129 (now renamed IMC 129) was crossed to Legend, a commercial spring *Brassica napus* variety. Legend has the following fatty acid composition:  $C_{16:0}$  - 3.8%,  $C_{18:0}$  - 2.1%,  $C_{18:1}$  - 63.1%,  $C_{18:2}$  - 17.8%,  $C_{18:3}$  - 9.3%.

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The cross and progeny resulting from were coded as 89B60303.

The  $F_1$  seed resulting from the cross was planted in the greenhouse and self-pollinated to produce  $F_2$  seed.

5 The  $F_2$  seed was planted in the field for evaluation. Individual plants were selected in the field for agronomic characteristics. At maturity, the  $F_3$  seed was harvested from each selected plant and analyzed for fatty acid composition.

10 Individuals which had fatty acid profiles similar to the high oleic acid parent (IMC 129) were advanced back to the field. Seeds ( $F_3$ ) of selected individuals were planted in the field as selfing rows and in plots for preliminary yield and agronomic evaluations. At  
15 flowering the  $F_3$  plants in the selfing rows were self-pollinated. At maturity the  $F_4$  seed was harvested from individual plants to determine fatty acid composition. Yield of the individual selections was determined from the harvested plots.

20 Based on fatty acid composition of the individual plants and yield and agronomic characteristics of the plots  $F_4$  lines were selected and advanced to the next generation in the greenhouse. Five plants from each selected line were self-pollinated. At maturity the  $F_5$   
25 seed was harvested from each and analyzed for fatty acid composition.

The  $F_5$  line with the highest oleic fatty profile was advanced to the field as a selfing row. The remaining  $F_5$  seed from the five plants was bulked together  
30 for planting the yield plots in the field. At flowering, the  $F_5$  plants in each selfing-row were self-pollinated. At maturity the  $F_6$  self-pollinated seed was harvest from the selfing row to determine fatty acid composition and select for the high oleic acid trait. Yield of the



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individual selections was determined from the harvested plots.

Fifteen  $F_6$  lines having the high oleic fatty profile of IMC 129 and the desired agronomic characteristics were advanced to the greenhouse to increase seed for field trialing. At flowering the  $F_6$  plants were self-pollinated. At maturity the  $F_7$  seed was harvested and analyzed for fatty acid composition. Three  $F_7$  seed lines which had fatty acid profiles most similar to IMC 129 (Table XIII) were selected and planted in the field as selfing rows, the remaining seed was bulked together for yield trialing. The high oleic fatty acid profile of IMC 129 was maintained through seven generations of selection for fatty acid and agronomic traits in an agronomic background of *Brassica napus* which was different from the parental lines. Thus, the genetic trait from IMC 129 for high oleic acid can be used in the development of new high oleic *Brassica napus* varieties.

TABLE XIII

Fatty Acid Composition of Advanced Breeding Generation with High Oleic Acid Trait (IMC 129 X Legend)

F <sub>7</sub> Selections of 89B60303	Fatty Acid Composition(%)				
	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>
93.06194	3.8	1.6	78.3	7.7	4.4
93.06196	4.0	2.8	77.3	6.8	3.4
93.06198	3.7	2.2	78.0	7.4	4.2

The high oleic acid trait of IMC 129 was also introduced into a different genetic background by combining crossing and selection methods with the generation of dihaploid populations from the microspores of the  $F_1$  hybrids. IMC 129 was crossed to Hyola 41, a commercial spring *Brassica napus* variety. Hyola 41 has the following fatty acid composition: C<sub>16:0</sub> - 3.8%, C<sub>18:0</sub> -

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2.7%,  $C_{18:1}$  - 64.9%,  $C_{18:2}$  - 16.2%,  $C_{18:3}$  - 9.1%. The cross and progeny resulting from the cross were labeled 90DU.146.

The  $F_1$  seed was planted from the cross and a  
5 dihaploid ( $DH_1$ ) population was made from the  $F_1$   
microspores using standard procedures for *Brassica napus*.  
Each  $DH_1$  plant was self-pollinated at flowering to produce  
 $DH_1$  seed. At maturity the  $DH_1$  seed was harvested and  
analyzed for fatty acid composition.  $DH_1$  individuals  
10 which expressed the high oleic fatty acid profile of IMC  
129 were advanced to the next generation in the  
greenhouse. For each individual selected five  $DH_1$  seeds  
were planted. At flowering the  $DH_1$  plants were self-  
pollinated. At maturity the  $DH_1$  seed was harvested and  
15 analyzed for fatty acid composition. The  $DH_1$  seed which  
was similar in fatty acid composition to the IMC 129  
parent was advanced to the field as a selfing row. The  
remaining  $DH_1$  seed of that group was bulked and planted in  
plots to determine yield and agronomic characteristics of  
20 the line. At flowering individual  $DH_1$  plants in the  
selfing row were self-pollinated. At maturity the  $DH_1$   
seed was harvested from the individual plants to  
determine fatty acid composition. Yield of the  
selections was determined from the harvested plots.  
25 Based on fatty acid composition, yield and agronomic  
characteristics selections were advanced to the next  
generation in the greenhouse. The  $DH_1$  seed produced in  
the greenhouse by self-pollination was analyzed for fatty  
acid composition. Individuals which were similar to the  
30 fatty acid composition of the IMC 129 parent were  
advanced to the field to test for fatty acid stability  
and yield evaluation. The harvested  $DH_1$  seed from six  
locations maintained the fatty acid profile of the IMC  
129 parent (Table XIV).

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TABLE XIV

Fatty Acid Composition of Advanced Dihaploid Breeding  
Generation with High Oleic Acid Trait  
(IMC 129 X Hyola41)

5	DH5 of 90DU.146 at Multiple Locations	Fatty Acid Composition(%)				
		C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>
	Aberdeen	3.7	2.6	75.4	8.1	7.2
10	Blackfoot	3.3	2.4	75.5	8.8	7.5
	Idaho Falls	3.7	3.1	75.0	7.5	8.1
	Rexberg	3.9	3.7	75.3	7.0	6.5
	Swan Valley	3.5	3.4	74.5	7.0	7.3
	Lamont	3.9	2.8	72.0	10.1	8.4

15

EXAMPLE 10Canola Lines Q508 and Q4275

Seeds of the *B. napus* line IMC-129 were  
mutagenized with methyl N-nitrosoguanidine (MNNG). The  
MNNG treatment consisted of three parts: pre-soak,  
20 mutagen application, and wash. A 0.05M Sorenson's  
phosphate buffer was used to maintain pre-soak and  
mutagen treatment pH at 6.1. Two hundred seeds were  
treated at one time on filter paper (Whatman #3M) in a  
petri dish (100mm x 15mm). The seeds were pre-soaked in  
25 15 mls of 0.05M Sorenson's buffer, pH 6.1, under  
continued agitation for two hours. At the end of the  
pre-soak period, the buffer was removed from the plate.

A 10mM concentration of MNNG in 0.05M Sorenson's  
buffer, pH 6.1, was prepared prior to use. Fifteen ml of  
30 10m MNNG was added to the seeds in each plate. The seeds  
were incubated at 22°C±3°C in the dark under constant  
agitation for four (4) hours. At the end of the  
incubation period, the mutagen solution was removed.

The seeds were washed with three changes of  
35 distilled water at 10 minute intervals. The fourth wash

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was for thirty minutes. This treatment regime produced an LD60 population.

Treated seeds were planted in standard greenhouse potting soil and placed into an environmentally controlled greenhouse. The plants were grown under sixteen hours of light. At flowering, the racemes were bagged to produce selfed seed. At maturity, the M2 seed was harvested. Each M2 line was given an identifying number. The entire MNNG-treated seed population was designated as the Q series.

Harvested M2 seeds were planted in the greenhouse. The growth conditions were maintained as previously described. The racemes were bagged at flowering for selfing. At maturity, the selfed M3 seed was harvested and analyzed for fatty acid composition. For each M3 seed line, approximately 10-15 seeds were analyzed in bulk as described in Example 1.

High oleic-low linoleic M3 lines were selected from the M3 population using a cutoff of >82% oleic acid and <5.0% linoleic. From the first 1600 M3 lines screened for fatty acid composition, Q508 was identified. The Q508 M3 generation was advanced to the M4 generation in the greenhouse. Table XV shows the fatty acid composition of Q508 and IMC 129. The M4 selfed seed maintained the selected high oleic-low linoleic acid phenotype (Table XVI).

**TABLE XV**

Fatty Acid Composition of A129 and High  
Oleic Acid M3 Mutant Q508

Line #	16:0	18:0	18:1	18:2	18:3
A129*	4.0	2.4	77.7	7.8	4.2
Q508	3.9	2.1	84.9	2.4	2.9

\*Fatty acid composition of A129 is the average of 50 self-pollinated plants grown with the M3 population

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M<sub>4</sub> generation Q508 plants had poor agronomic qualities in the field compared to Westar. Typical plants were slow growing relative to Westar, lacked early vegetative vigor, were short in stature, tended to be chlorotic and had short pods. The yield of Q508 was very low compared to Westar.

The M<sub>4</sub> generation Q508 plants in the greenhouse tended to be reduced in vigor compared to Westar. However, Q508 yields in the greenhouse were greater than Q508 yields in the field.

**TABLE XVI**

Fatty Acid Composition of Seed Oil  
from Greenhouse-Grown Q508, IMC 129 and Westar.

Line	16:0	18:0	18:1	18:2	18:3	FDA Sats
IMC 129 <sup>a</sup>	4.0	2.4	77.7	7.8	4.2	6.4
Westar <sup>b</sup>	3.9	1.9	67.5	17.6	7.4	>5.8
Q508 <sup>c</sup>	3.9	2.1	84.9	2.4	2.9	6.0

<sup>a</sup>Average of 50 self-pollinated plants

<sup>b</sup>Data from Example 1

<sup>c</sup>Average of 50 self-pollinated plants

Nine other M<sub>4</sub> high-oleic low-linoleic lines were also identified: Q3603, Q3733, Q4249, Q6284, Q6601, Q6761, Q7415, Q4275, and Q6676. Some of these lines had good agronomic characteristics and an elevated oleic acid level in seeds of about 80% to about 84%.

Q4275 was crossed to the variety Cyclone. After selfing for seven generations, mature seed was harvested from 93GS34-179, a progeny line of the Q4275 Cyclone cross. Referring to Table XVII, fatty acid composition of a bulk seed sample shows that 93GS34 retained the seed fatty acid composition of Q4275. 93GS34-179 also maintained agronomically desirable characteristics.

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After more than seven generations of selfing of Q4275, plants of Q4275, IMC 129 and 93GS34 were field grown during the summer season. The selections were tested in 4 replicated plots (5 feet X 20 feet) in a randomized block design. Plants were open pollinated. No selfed seed was produced. Each plot was harvested at maturity, and a sample of the bulk harvested seed from each line was analyzed for fatty acid composition as described above. The fatty acid compositions of the selected lines are shown in Table XVII.

**Table XVII**  
**Fatty Acid Composition of**  
**Field Grown IMC 129, Q4275 and 93GS34 Seeds**

Line	Fatty Acid Composition (%)					
	C <sub>16:0</sub>	C <sub>18:0</sub>	C <sub>18:1</sub>	C <sub>18:2</sub>	C <sub>18:3</sub>	FDA Sats
IMC 129	3.3	2.4	76.7	8.7	5.2	5.7
Q4275	3.7	3.1	82.1	4.0	3.5	6.8
93GS34-179	2.6	2.7	85.0	2.8	3.3	5.3

The results shown in Table XVII show that Q4275 maintained the selected high oleic - low linoleic acid phenotype under field conditions. The agronomic characteristics of Q4275 plants were superior to those of Q508.

M<sub>4</sub> generation Q508 plants were crossed to a dihaploid selection of Westar, with Westar serving as the female parent. The resulting F<sub>1</sub> seed was termed the 92EF population. About 126 F<sub>1</sub> individuals that appeared to have better agronomic characteristics than the Q508 parent were selected for selfing. A portion of the F<sub>2</sub> seed from such individuals was replanted in the field. Each F<sub>2</sub> plant was selfed and a portion of the resulting F<sub>3</sub> seed was analyzed for fatty acid composition. The content of oleic acid in F<sub>3</sub> seed ranged from 59 to 79%.

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No high oleic (>80%) individuals were recovered with good agronomic type.

A portion of the F<sub>2</sub> seed of the 92EF population was planted in the greenhouse to analyze the genetics of the Q508 line. F<sub>3</sub> seed was analyzed from 380 F<sub>2</sub> individuals. The C<sub>18:1</sub> levels of F<sub>3</sub> seed from the greenhouse experiment is depicted in Figure 1. The data were tested against the hypothesis that Q508 contains two mutant genes that are semi-dominant and additive: the original IMC 129 mutation as well as one additional mutation. The hypothesis also assumes that homozygous Q508 has greater than 85% oleic acid and homozygous Westar has 62-67% oleic acid. The possible genotypes at each gene in a cross of Q508 by Westar may be designated as:

AA = Westar Fad2<sup>a</sup>

BB = Westar Fad2<sup>b</sup>

aa = Q508 Fad2<sup>a-</sup>

bb = Q508 Fad2<sup>b-</sup>

Assuming independent segregation, a 1:4:6:4:1 ratio of phenotypes is expected. The phenotypes of heterozygous plants are assumed to be indistinguishable and, thus, the data were tested for fit to a 1:14:1 ratio of homozygous Westar: heterozygous plants: homozygous Q508.

Phenotypic Ratio	# of Westar Alleles	Genotype
1	4	AABB (Westar)
4	3	AABb, AaBB, AABb, AaBB
6	2	AaBb, AAbb, AaBb, AaBb, aaBB, AaBb
4	1	Aabb, aaBb, Aabb, aaBb
1	0	aabb (Q508)

Using Chi-square analysis, the oleic acid data fit a 1:14:1 ratio. It was concluded that Q508 differs from

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Westar by two major genes that are semi-dominant and additive and that segregate independently. By comparison, the genotype of IMC 129 is aaBB.

The fatty acid composition of representative F<sub>3</sub> individuals having greater than 85% oleic acid in seed oil is shown in Table XVIII. The levels of saturated fatty acids are seen to be decreased in such plants, compared to Westar.

**TABLE XVIII**

10 92EF F<sub>3</sub> Individuals with >85% C<sub>18:1</sub> in Seed Oil

F3 Plant Identifier	Fatty Acid Composition (%)					
	C16:0	C18:0	C18:1	C18:2	C18:3	FDASA
+38068	3.401	1.582	85.452	2.134	3.615	4.983
+38156	3.388	1.379	85.434	2.143	3.701	4.767
15 +38171	3.588	1.511	85.289	2.367	3.425	5.099
+38181	3.75	1.16	85.312	2.968	3.819	4.977
+38182	3.529	0.985	85.905	2.614	3.926	4.56
+38191	3.364	1.039	85.737	2.869	4.039	4.459
+38196	3.557	1.182	85.054	2.962	4.252	4.739
20 +38202	3.554	1.105	86.091	2.651	3.721	4.713
+38220	3.093	1.16	86.421	1.931	3.514	4.314
+38236	3.308	1.349	85.425	2.37	3.605	4.718
+38408	3.617	1.607	85.34	2.33	3.562	5.224
+38427	3.494	1.454	85.924	2.206	3.289	4.948
25 +38533	3.64	1.319	85.962	2.715	3.516	4.959



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EXAMPLE 11Leaf and Root Fatty Acid Profiles of Canola  
Lines IMC-129, Q508, and Westar

Plants of Q508, IMC 129 and Westar were grown in  
5 the greenhouse. Mature leaves, primary expanding leaves,  
petioles and roots were harvested at the 6-8 leaf stage,  
frozen in liquid nitrogen and stored at  $-70^{\circ}\text{C}$ . Lipid  
extracts were analyzed by GLC as described in Example 1.  
The fatty acid profile data are shown in Table XIX.

10 The data in Table XIX indicate that total leaf  
lipids in Q508 are higher in  $\text{C}_{18:1}$  content than the  $\text{C}_{18:2}$   
plus  $\text{C}_{18:3}$  content. The reverse is true for Westar and IMC  
129. The difference in total leaf lipids between Q508  
and IMC 129 is consistent with the hypothesis that a  
15 second Fad2 gene is mutated in Q508.

The  $\text{C}_{16:3}$  content in the total lipid fraction was  
about the same for all three lines, suggesting that the  
plastid FadC gene product was not affected by the Q508  
mutations. To confirm that the FadC gene was not  
20 mutated, chloroplast lipids were separated and analyzed.  
No changes in chloroplast  $\text{C}_{16:1}$ ,  $\text{C}_{16:2}$  or  $\text{C}_{16:3}$  fatty acids  
were detected in the three lines. The similarity in  
plastid leaf lipids among Q508, Westar and IMC 129 is  
consistent with the hypothesis that the second mutation  
25 in Q508 affects a microsomal Fad2 gene and not a plastid  
FadC gene.

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**TABLE XIX**

	MATURE LEAF			EXPANDING LEAF			PETIOLE			ROOT		
	West.	129	3Q508	West.	129	3Q508	West.	129	3Q508	West.	129	3Q508
16:0	12.1	11.9	10.1	16.4	16.1	11.3	21.7	23.5	11.9	21.1	21.9	12.0
16:1	0.8	0.6	1.1	0.7	0.6	1.1	1.0	1.3	1.4	-	-	-
16:2	2.3	2.2	2.0	2.8	3.1	2.8	1.8	2.2	1.8	-	-	-
16:3	14.7	15.0	14.0	6.3	5.4	6.9	5.7	4.6	5.7	-	-	-
18:0	2.2	1.6	1.2	2.5	2.8	1.5	3.7	4.0	1.6	3.6	2.9	2.5
18:1	2.8	4.9	16.7	3.8	8.3	38.0	4.9	12.9	46.9	3.5	6.1	68.8
18:2	12.6	11.5	6.8	13.3	13.8	4.9	20.7	18.3	5.2	28.0	30.4	4.4
18:3	50.6	50.3	46.0	54.2	50.0	33.5	40.4	33.2	25.3	43.8	38.7	12.3

10

**EXAMPLE 12**

Sequences of Mutant and Wild-Type Delta-12 Fatty Acid  
Desaturases from *B. napus*

Primers specific for the FAD2 structural gene were used to clone the entire open reading frame (ORF) of the D and F 12-DES genes by reverse transcriptase polymerase chain reaction (RT-PCR). RNA from seeds of IMC 129, Q508 and Westar plants was isolated by standard methods and was used as template. The RT-amplified fragments were used for nucleotide sequence determination. The DNA sequence of each gene from each line was determined from both strands by standard dideoxy sequencing methods.

Sequence analysis revealed a G to A transversion at nucleotide 316 (from the translation initiation codon) of the D gene in both IMC 129 (SEQ ID NO:3) and Q508, compared to the sequence of Westar (SEQ ID NO:1). The transversion changes the codon at this position from GAG to AAG and results in a non-conservative substitution of glutamic acid, an acidic residue, for lysine a basic residue. The presence of the same mutation in both lines was expected since the Q508 line was derived from IMC 129. The same base change was also detected in Q508

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and IMC 129 when RNA from leaf tissue was used as template.

The G to A mutation at nucleotide 316 was confirmed by sequencing several independent clones  
5 containing fragments amplified directly from genomic DNA of IMC 129 and Westar. These results eliminated the possibility of a rare mutation introduced during reverse transcription and PCR in the RT-PCR protocol. It was concluded that the IMC 129 mutant is due to a single base  
10 transversion at nucleotide 316 in the coding region of the D gene of rapeseed microsomal delta 12-desaturase.

A single base transition from T to A at nucleotide 515 of the F gene was detected in Q508 compared to the Westar sequence. The mutation changes the codon at this  
15 position from CTC to CAC, resulting in the non-conservative substitution of a non-polar residue, leucine, for a polar residue, histidine, in the resulting gene product. No mutations were found in the F gene sequence of IMC 129 compared to the F gene sequence of  
20 Westar.

These data support the conclusion that a mutation in a delta-12 desaturase gene sequence results in alterations in the fatty acid profile of plants containing such a mutated gene. Moreover, the data show  
25 that when a plant line or species contains two delta-12 desaturase loci, the fatty acid profile of an individual having two mutated loci differs from the fatty acid profile of an individual having one mutated locus.

The mutation in the D gene of IMC 129 and Q508  
30 mapped to a region having a conserved amino acid motif (His-Xaa-Xaa-Xaa-His) found in cloned delta-12 and delta-15 membrane bound-desaturases (Table XX).

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**Table XX**

Alignment of Amino Acid Sequences  
of Cloned Canola Membrane Bound-Desaturases

	Desaturase Gene	Sequence <sup>a</sup>	Position
5	Canola-fad2-D (mutant)	AHKCGH	109-114
	Canola-Fad2-D	AHECGH	109-114
	Canola-Fad2-F	AHECGH	109-114
	Canola-FadC	<u>GH</u> <b>D</b> CAH	170-175
	Canola-fad3 (mutant)	<u>GH</u> KCGH	94-99
10	Canola-Fad3	<u>GH</u> <b>D</b> CGH	94-99
	Canola-FadD	<u>GH</u> <b>D</b> CGH	125-130

(FadD = Plastid delta 15, Fad3 = Microsomal delta-15),  
(FadC = Plastid delta-12, Fad2 = Microsomal delta-12)

<sup>a</sup> One letter amino acid code; conservative substitutions  
15 are underlined; non-conservative substitutions are in  
bold.

**EXAMPLE 13**

Transcription and Translation of Microsomal Delta-12  
Fatty Acid Desaturases

20 Transcription in vivo was analyzed by RT-PCR  
analysis of stage II and stage III developing seeds and  
leaf tissue. The primers used to specifically amplify  
12-DES F gene RNA from the indicated tissues were sense  
primer 5'-GGATATGATGATGGTGAAAGA-3' and antisense primer  
25 5'-TCTTTCACCATCATCATATCC-3'. The primers used to  
specifically amplify 12-DES D gene RNA from the indicated  
tissues were sense primer 5'-GTTATGAAGCAAAGAAGAAAC-3' and  
antisense primer 5'-GTTTCTTCTTTGCTTCATAAC-3'. The  
results indicated that mRNA of both the D and F gene was  
30 expressed in seed and leaf tissues of IMC 129, Q508 and  
wild type Westar plants.

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*In vitro* transcription and translation analysis showed that a peptide of about 46 kD was made. This is the expected size of both the D gene product and the F gene product, based on sum of the deduced amino acid sequence of each gene and the cotranslational addition of a microsomal membrane peptide.

These results rule out the possibility that non-sense or frameshift mutations, resulting in a truncated polypeptide gene product, are present in either the mutant D gene or the mutant F gene. The data, in conjunction with the data of Example 12, support the conclusion that the mutations in Q508 and IMC 129 are in delta-12 fatty acid desaturase structural genes encoding desaturase enzymes, rather than in regulatory genes.

15

#### EXAMPLE 14

##### Development of Gene-Specific PCR Markers

Based on the single base change in the mutant D gene of IMC 129 described in above, two 5' PCR primers were designed. The nucleotide sequence of the primers differed only in the base (G for Westar and A for IMC 129) at the 3' end. The primers allow one to distinguish between mutant fad2-D and wild-type Fad2-D alleles in a DNA-based PCR assay. Since there is only a single base difference in the 5' PCR primers, the PCR assay is very sensitive to the PCR conditions such as annealing temperature, cycle number, amount, and purity of DNA templates used. Assay conditions have been established that distinguish between the mutant gene and the wild type gene using genomic DNA from IMC 129 and wild type plants as templates. Conditions may be further optimized by varying PCR parameters, particularly with variable crude DNA samples. A PCR assay distinguishing the single base mutation in IMC 129 from the wild type gene along with fatty acid composition analysis provides a means to

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simplify segregation and selection analysis of genetic crosses involving plants having a delta-12 fatty acid desaturase mutation.

#### EXAMPLE 15

##### 5     Transformation with Mutant and Wild Type Fad3 Genes

*B. napus* cultivar Westar was transformed with mutant and wild type Fad3 genes to demonstrate that the mutant Fad3 gene for canola cytoplasmic linoleic desaturase 15-DES is nonfunctional. Transformation and  
10   regeneration were performed using disarmed *Agrobacterium tumefaciens* essentially following the procedure described in WO 94/11516.

Two disarmed *Agrobacterium* strains were engineered, each containing a Ti plasmid having the  
15   appropriate gene linked to a seed-specific promoter and a corresponding termination sequence. The first plasmid, pIMC110, was prepared by inserting into a disarmed Ti vector the full length wild type Fad3 gene in sense orientation (nucleotides 208 to 1336 of SEQ ID 6 in WO  
20   93/11245), flanked by a napin promoter sequence positioned 5' to the Fad3 gene and a napin termination sequence positioned 3' to the Fad3 gene. The rapeseed napin promoter is described in EP 0255378.

The second plasmid, pIMC205, was prepared by  
25   inserting a mutated Fad3 gene in sense orientation into a disarmed Ti vector. The mutant sequence contained mutations at nucleotides 411 and 413 of the microsomal Fad3 gene described in WO93/11245, thus changing the sequence for codon 96 from GAC to AAG. The amino acid at  
30   codon 96 of the gene product was thereby changed from aspartic acid to lysine. See Table XX. A bean (*Phaseolus vulgaris*) phaseolin (7S seed storage protein) promoter fragment of 495 base pairs, starting with 5'-TGGTCTTTTGGT-3', was placed 5' to the mutant Fad3 gene  
35   and a phaseolin termination sequence was placed 3' to the

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mutant Fad3 gene. The phaseolin sequence is described in Doyle et al., (1986) J. Biol. Chem. 261:9228-9238) and Slightom et al., (1983) Proc. Natl. Acad. Sci. USA 80:1897-1901.

5           The appropriate plasmids were engineered and transferred separately to *Agrobacterium* strain LBA4404. Each engineered strain was used to infect 5 mm segments of hypocotyl explants from Westar seeds by cocultivation. Infected hypocotyls were transferred to callus medium  
10 and, subsequently, to regeneration medium. Once discernable stems formed from the callus, shoots were excised and transferred to elongation medium. The elongated shoots were cut, dipped in Rootone™, rooted on an agar medium and transplanted to potting soil to obtain  
15 fertile T1 plants. T2 seeds were obtained by selfing the resulting T1 plants.

          Fatty acid analysis of T2 seeds was carried out as described above. The results are summarized in Table XXI. Of the 40 transformants obtained using the pIMC110  
20 plasmid, 17 plants demonstrated wild type fatty acid profiles and 16 demonstrated overexpression. A proportion of the transformants are expected to display an overexpression phenotype when a functioning gene is transformed in sense orientation into plants.

25           Of the 307 transformed plants having the pIMC205 gene, none exhibited a fatty acid composition indicative of overexpression. This result indicates that the mutant fad3 gene product is non-functional, since some of the transformants would have exhibited an overexpression  
30 phenotype if the gene product were functional.

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**Table XXI**  
**Overexpression and Co-suppression Events in**  
**Westar Populations Transformed with pIMC205 or pIMC110.**

Construct	Number of Transformants	$\alpha$ -Linolenic Acid Range (%)	Overexpression Events (>10% linolenic)	Co-Suppression Events (<4.0% linolenic)	Wild Type Events
pIMC110	40	2.4 - 20.6	16	7	17
pIMC205	307	4.6 - 10.4	0	0	307

Fatty acid compositions of representative transformed plants are presented in Table XXII. Lines 652-09 and 663-40 are representative of plants containing pIMC110 and exhibiting an overexpression and a co-suppression phenotype, respectively. Line 205-284 is representative of plants containing pIMC205 and having the mutant fad3 gene.

**Table XXII**  
**Fatty Acid Composition of T2 Seed**  
**From Westar Transformed With pIMC205 or pIMC110.**

Line	Fatty Acid Composition (%)				
	C16:0	C18:0	C18:1	C18:2	C18:3
652-09 pIMC110 overexpression	4.7	3.3	65.6	8.1	14.8
663-40 pIMC110 co-suppression	4.9	2.1	62.5	23.2	3.6
205-284 pIMC205	3.7	1.8	68.8	15.9	6.7

To the extent not already indicated, it will be understood by those of ordinary skill in the art that any one of the various specific embodiments herein described and illustrated may be further modified to incorporate features shown in other of the specific embodiments.

The foregoing detailed description has been provided for a better understanding of the invention only and no unnecessary limitation should be understood therefrom as some modifications will be apparent to those



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skilled in the art without deviating from the spirit and scope of the appended claims.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

- (i) APPLICANT: Cargill, Incorporated
- (ii) TITLE OF INVENTION: PLANTS HAVING MUTANT SEQUENCES THAT CONFER  
ALTERED FATTY ACID PROFILES
- (iii) NUMBER OF SEQUENCES: 8
- (iv) CORRESPONDENCE ADDRESS:
  - (A) ADDRESSEE: Fish & Richardson, P.C., P.A.
  - (B) STREET: 60 South Sixth Street, Suite 3300
  - (C) CITY: Minneapolis
  - (D) STATE: MN
  - (E) COUNTRY: USA
  - (F) ZIP: 55402
- (v) COMPUTER READABLE FORM:
  - (A) MEDIUM TYPE: Floppy disk
  - (B) COMPUTER: IBM PC compatible
  - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
  - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
- (vi) CURRENT APPLICATION DATA:
  - (A) APPLICATION NUMBER: PCT/US96/
  - (B) FILING DATE: 13-DEC-1996
  - (C) CLASSIFICATION:
- (vii) PRIOR APPLICATION DATA:
  - (A) APPLICATION NUMBER: US 08/572,027
  - (B) FILING DATE: 14-DEC-1995
  - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
  - (A) NAME: Ellinger, Mark S.
  - (B) REGISTRATION NUMBER: 34,812
  - (C) REFERENCE/DOCKET NUMBER: 07148/049WO1
- (ix) TELECOMMUNICATION INFORMATION:
  - (A) TELEPHONE: 612/335-5070
  - (B) TELEFAX: 612/288-9696

## (2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 1155 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA
- (iii) HYPOTHETICAL: NO
- (iv) ANTI-SENSE: NO
- (vi) ORIGINAL SOURCE:
  - (A) ORGANISM: Brassica napus
- (ix) FEATURE:
  - (D) OTHER INFORMATION: Wild type D form.

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

ATG Met 1	GGT Gly	GCA Ala	GGT Gly	GGA Gly 5	AGA Arg	ATG Met	CAA Gln	GTG Val	TCT Ser 10	CCT Pro	CCC Pro	TCC Ser	AAG Lys	AAG Lys 15	TCT Ser	48
GAA Glu	ACC Thr	GAC Asp	ACC Thr 20	ATC Ile	AAG Lys	CGC Arg	GTA Val	CCC Pro 25	TGC Cys	GAG Glu	ACA Thr	CCG Pro	CCC Pro 30	TTC Phe	ACT Thr	96
GTC Val	GGA Gly	GAA Glu 35	CTC Leu	AAG Lys	AAA Lys	GCA Ala	ATC Ile 40	CCA Pro	CCG Pro	CAC His	TGT Cys	TTC Phe 45	AAA Lys	CGC Arg	TCG Ser	144
ATC Ile 50	CCT Pro	CGC Arg	TCT Ser	TTC Phe	TCC Ser	TAC Tyr 55	CTC Leu	ATC Ile	TGG Trp	GAC Asp 60	ATC Ile	ATC Ile	ATA Ile	GCC Ala	TCC Ser	192
TGC Cys 65	TTC Phe	TAC Tyr	TAC Tyr	NTC Xaa	GCC Ala 70	ACC Thr	ACT Thr	TAC Tyr	TTC Phe	CCT Pro 75	CTC Leu	CTC Leu	CCT Pro	CAC His	CCT Pro 80	240
CTC Leu	TCC Ser	TAC Tyr	TTC Phe	GCC Ala 85	TGG Trp	CCT Pro	CTC Leu	TAC Tyr	TGG Trp 90	GCC Ala	TGC Cys	CAA Gln	GGG Gly	TGC Cys 95	GTC Val	288
CTA Leu	ACC Thr	GGC Gly	GTC Val 100	TGG Trp	GTC Val	ATA Ile	GCC Ala	CAC His 105	GAA Glu	TGC Cys	GGC Gly	CAC His	CAC His 110	GCC Ala	TTC Phe	336
AGC Ser	GAC Asp	TAC Tyr 115	CAG Gln	TGG Trp	CTT Leu	GAC Asp	GAC Asp 120	ACC Thr	GTC Val	GGT Gly	CTC Leu	ATC Ile 125	TTC Phe	CAC His	TCC Ser	384
TTC Phe 130	CTC Leu	CTC Leu	GTC Val	CCT Pro	TAC Tyr	TTC Phe 135	TCC Ser	TGG Trp	AAG Lys	TAC Tyr 140	AGT Ser	CAT His	CGC Arg	AGC Ser	CAC His	432
CAT His 145	TCC Ser	AAC Asn	ACT Thr	GGC Gly	TCC Ser 150	CTC Leu	GAG Glu	AGA Arg	GAC Asp 155	GAA Val	GTG Val	TTT Phe	GTC Val	CCC Pro	AAG Lys 160	480
AAG Lys	AAG Lys	TCA Ser	GAC Asp	ATC Ile 165	AAG Lys	TGG Trp	TAC Tyr	GGC Gly	AAG Lys 170	TAC Tyr	CTC Leu	AAC Asn	AAC Asn	CCT Pro 175	TTG Leu	528
GGA Gly	CGC Arg	ACC Thr	GTG Val 180	ATG Met	TTA Leu	ACG Thr	GTT Val	CAG Gln 185	TTC Phe	ACT Thr	CTC Leu	GGC Gly	TGG Trp 190	CCG Pro	TTG Leu	576
TAC Tyr	TTA Leu 195	GCC Ala	TTC Phe	AAC Asn	GTC Val	TCG Ser	GGA Gly 200	AGA Arg	CCT Pro	TAC Tyr	GAC Asp 205	GGC Gly	GGC Gly	TTC Phe	CGT Arg	624
TGC Cys 210	CAT His	TTC Phe	CAC His	CCC Pro	AAC Asn	GCT Ala 215	CCC Pro	ATC Ile	TAC Tyr	AAC Asn	GAC Asp 220	CGC Arg	GAG Glu	CGT Arg	CTC Leu	672
CAG Gln 225	ATA Ile	TAC Tyr	ATC Ile	TCC Ser	GAC Asp 230	GCT Ala	GGC Gly	ATC Ile	CTC Leu	GCC Ala 235	GTC Val	TGC Cys	TAC Tyr	GGT Gly	CTC Leu 240	720
TTC Phe	CGT Arg	TAC Tyr	GCC Ala	GCC Ala 245	GGC Gly	CAG Gln	GGA Gly	GTG Val	GCC Ala 250	TCG Ser	ATG Met	GTC Val	TGC Cys	TTC Phe 255	TAC Tyr	768
GGA Gly	GTC Val	CCG Pro	CTT Leu 260	CTG Leu	ATT Ile	GTC Val	AAT Asn	GGT Gly 265	TTC Phe	CTC Leu	GTG Val	TTG Leu	ATC Ile 270	ACT Thr	TAC Tyr	816

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TTG CAG CAC ACG CAT CCT TCC CTG CCT CAC TAC GAT TCG TCC GAG TGG	864
Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp	
275 280 285	
GAT TGG TTC AGG GGA GCT TTG GCT ACC GTT GAC AGA GAC TAC GGA ATC	912
Asp Trp Phe Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile	
290 295 300	
TTG AAC AAG GTC TTC CAC AAT ATT ACC GAC ACG CAC GTG GCC CAT CAT	960
Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His	
305 310 315 320	
CCG TTC TCC ACG ATG CCG CAT TAT CAC GCG ATG GAA GCT ACC AAG GCG	1008
Pro Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala	
325 330 335	
ATA AAG CCG ATA CTG GGA GAG TAT TAT CAG TTC GAT GGG ACG CCG GTG	1056
Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Phe Asp Gly Thr Pro Val	
340 345 350	
GTT AAG GCG ATG TGG AGG GAG GCG AAG GAG TGT ATC TAT GTG GAA CCG	1104
Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro	
355 360 365	
GAC AGG CAA GGT GAG AAG AAA GGT GTG TTC TGG TAC AAC AAT AAG TTA T	1153
Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu	
370 375 380	
GA	1155

## (2) INFORMATION FOR SEQ ID NO:2:

## (i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 384 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: protein

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Met	Gly	Ala	Gly	Gly	Arg	Met	Gln	Val	Ser	Pro	Pro	Ser	Lys	Lys	Ser
1				5					10					15	
Glu	Thr	Asp	Thr	Ile	Lys	Arg	Val	Pro	Cys	Glu	Thr	Pro	Pro	Phe	Thr
			20					25					30		
Val	Gly	Glu	Leu	Lys	Lys	Ala	Ile	Pro	Pro	His	Cys	Phe	Lys	Arg	Ser
		35					40					45			
Ile	Pro	Arg	Ser	Phe	Ser	Tyr	Leu	Ile	Trp	Asp	Ile	Ile	Ile	Ala	Ser
	50					55					60				
Cys	Phe	Tyr	Tyr	Xaa	Ala	Thr	Thr	Tyr	Phe	Pro	Leu	Leu	Pro	His	Pro
	65				70					75					80
Leu	Ser	Tyr	Phe	Ala	Trp	Pro	Leu	Tyr	Trp	Ala	Cys	Gln	Gly	Cys	Val
			85						90					95	
Leu	Thr	Gly	Val	Trp	Val	Ile	Ala	His	Glu	Cys	Gly	His	His	Ala	Phe
			100				105						110		
Ser	Asp	Tyr	Gln	Trp	Leu	Asp	Asp	Thr	Val	Gly	Leu	Ile	Phe	His	Ser
		115				120						125			
Phe	Leu	Leu	Val	Pro	Tyr	Phe	Ser	Trp	Lys	Tyr	Ser	His	Arg	Ser	His
	130					135					140				

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His Ser Asn Thr Gly Ser Leu Glu Arg Asp Glu Val Phe Val Pro Lys
145          150          155          160

Lys Lys Ser Asp Ile Lys Trp Tyr Gly Lys Tyr Leu Asn Asn Pro Leu
          165          170          175

Gly Arg Thr Val Met Leu Thr Val Gln Phe Thr Leu Gly Trp Pro Leu
          180          185          190

Tyr Leu Ala Phe Asn Val Ser Gly Arg Pro Tyr Asp Gly Gly Phe Arg
          195          200          205

Cys His Phe His Pro Asn Ala Pro Ile Tyr Asn Asp Arg Glu Arg Leu
210          215          220

Gln Ile Tyr Ile Ser Asp Ala Gly Ile Leu Ala Val Cys Tyr Gly Leu
225          230          235          240

Phe Arg Tyr Ala Ala Gly Gln Gly Val Ala Ser Met Val Cys Phe Tyr
          245          250          255

Gly Val Pro Leu Leu Ile Val Asn Gly Phe Leu Val Leu Ile Thr Tyr
          260          265          270

Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp
          275          280          285

Asp Trp Phe Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile
290          295          300

Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His
305          310          315          320

Pro Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala
          325          330          335

Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Phe Asp Gly Thr Pro Val
          340          345          350

Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro
          355          360          365

Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu
370          375          380

```

## (2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 1155 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA
- (iii) HYPOTHETICAL: NO
- (iv) ANTI-SENSE: NO
- (vi) ORIGINAL SOURCE:
  - (A) ORGANISM: Brassica napus
- (vii) IMMEDIATE SOURCE:
  - (B) CLONE: IMC129
- (ix) FEATURE:
  - (D) OTHER INFORMATION: G to A transversion mutation at nucleotide 316 of the D form.

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## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

ATG Met 1	GGT Gly	GCA Ala	GGT Gly	GGA Gly 5	AGA Arg	ATG Met	CAA Gln	GTG Val	TCT Ser 10	CCT Pro	CCC Pro	TCC Ser	AAG Lys	AAG Lys 15	TCT Ser	48
GAA Glu	ACC Thr	GAC Asp	ACC Thr 20	ATC Ile	AAG Lys	CGC Arg	GTA Val	CCC Pro 25	TGC Cys	GAG Glu	ACA Thr	CCG Pro	CCC Pro 30	TTC Phe	ACT Thr	96
GTC Val	GGA Gly	GAA Glu 35	CTC Leu	AAG Lys	AAA Lys	GCA Ala	ATC Ile 40	CCA Pro	CCG Pro	CAC His	TGT Cys	TTC Phe 45	AAA Lys	CGC Arg	TCG Ser	144
ATC Ile 50	CCT Pro	CGC Arg	TCT Ser	TTC Phe	TCC Ser	TAC Tyr 55	CTC Leu	ATC Ile	TGG Trp	GAC Asp 60	ATC Ile	ATC Ile	ATA Ile	GCC Ala	TCC Ser	192
TGC Cys 65	TTC Phe	TAC Tyr	TAC Tyr	NTC Xaa	GCC Ala 70	ACC Thr	ACT Thr	TAC Tyr	TTC Phe	CCT Pro 75	CTC Leu	CTC Leu	CCT Pro	CAC His	CCT Pro 80	240
CTC Leu	TCC Ser	TAC Tyr	TTC Phe	GCC Ala 85	TGG Trp	CCT Pro	CTC Leu	TAC Tyr	TGG Trp 90	GCC Ala	TGC Cys	CAA Gln	GGG Gly	TGC Cys 95	GTC Val	288
CTA Leu	ACC Thr	GGC Gly	GTC Val 100	TGG Trp	GTC Val	ATA Ile	GCC Ala	CAC His 105	AAG Lys	TGC Cys	GGC Gly	CAC His	CAC His 110	GCC Ala	TTC Phe	336
AGC Ser	GAC Asp	TAC Gln 115	CAG Gln	TGG Trp	CTT Leu	GAC Asp	GAC Asp 120	ACC Thr	GTC Val	GGT Gly	CTC Leu	ATC Ile 125	TTC Phe	CAC His	TCC Ser	384
TTC Phe 130	CTC Leu	CTC Leu	GTC Val	CCT Pro	TAC Tyr	TTC Phe 135	TCC Ser	TGG Trp	AAG Lys	TAC Tyr	AGT Ser 140	CAT His	CGC Arg	AGC Ser	CAC His	432
CAT His 145	TCC Ser	AAC Asn	ACT Thr	GGC Gly	TCC Ser 150	CTC Leu	GAG Glu	AGA Arg	GAC Asp	GAA Glu 155	GTG Val	TTT Phe	GTC Val	CCC Pro	AAG Lys 160	480
AAG Lys	AAG Lys	TCA Ser	GAC Asp 165	ATC Ile	AAG Lys	TGG Trp	TAC Tyr	GGC Gly	AAG Lys 170	TAC Tyr	CTC Leu	AAC Asn	AAC Asn	CCT Pro 175	TTG Leu	528
GGA Gly	CGC Arg	ACC Thr	GTG Val 180	ATG Met	TTA Leu	ACG Thr	GTT Val	CAG Gln 185	TTC Phe	ACT Thr	CTC Leu	GGC Gly	TGG Trp 190	CCG Pro	TTG Leu	576
TAC Tyr	TTA Leu 195	GCC Ala	TTC Phe	AAC Asn	GTC Val	TCG Ser	GGA Gly 200	AGA Arg	CCT Pro	TAC Tyr	GAC Asp	GGC Gly 205	GGC Gly	TTC Phe	CGT Arg	624
TGC Cys 210	CAT His	TTC Phe	CAC His	CCC Pro	AAC Asn	GCT Ala 215	CCC Pro	ATC Ile	TAC Tyr	AAC Asn	GAC Asp 220	CGC Arg	GAG Glu	CGT Arg	CTC Leu	672
CAG Gln 225	ATA Ile	TAC Tyr	ATC Ile	TCC Ser	GAC Asp 230	GCT Ala	GGC Gly	ATC Ile	CTC Leu	GCC Ala 235	GTC Val	TGC Cys	TAC Tyr	GGT Gly	CTC Leu 240	720
TTC Phe	CGT Arg	TAC Tyr	GCC Ala 245	GCC Ala	GGC Gly	CAG Gln	GGA Gly	GTG Val	GCC Ala 250	TCG Ser	ATG Met	GTC Val	TGC Cys	TTC Phe 255	TAC Tyr	768
GGA Gly	GTC Val	CCG Pro	CTT Leu 260	CTG Leu	ATT Ile	GTC Val	AAT Asn	GGT Gly 265	TTC Phe	CTC Leu	GTG Val	TTG Leu	ATC Ile 270	ACT Thr	TAC Tyr	816

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TTG CAG CAC ACG CAT CCT TCC CTG CCT CAC TAC GAT TCG TCC GAG TGG	864
Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp	
275 280 285	
GAT TGG TTC AGG GGA GCT TTG GCT ACC GTT GAC AGA GAC TAC GGA ATC	912
Asp Trp Phe Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile	
290 295 300	
TTG AAC AAG GTC TTC CAC AAT ATT ACC GAC ACG CAC GTG GCC CAT CAT	960
Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His	
305 310 315 320	
CCG TTC TCC ACG ATG CCG CAT TAT CAC GCG ATG GAA GCT ACC AAG GCG	1008
Pro Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala	
325 330 335	
ATA AAG CCG ATA CTG GGA GAG TAT TAT CAG TTC GAT GGG ACG CCG GTG	1056
Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Phe Asp Gly Thr Pro Val	
340 345 350	
GTT AAG GCG ATG TGG AGG GAG GCG AAG GAG TGT ATC TAT GTG GAA CCG	1104
Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro	
355 360 365	
GAC AGG CAA GGT GAG AAG AAA GGT GTG TTC TGG TAC AAC AAT AAG TTA T	1153
Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu	
370 375 380	
GA	1155

## (2) INFORMATION FOR SEQ ID NO:4:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 384 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: protein

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Met Gly Ala Gly Gly Arg Met Gln Val Ser Pro Pro Ser Lys Lys Ser	
1 5 10 15	
Glu Thr Asp Thr Ile Lys Arg Val Pro Cys Glu Thr Pro Pro Phe Thr	
20 25 30	
Val Gly Glu Leu Lys Lys Ala Ile Pro Pro His Cys Phe Lys Arg Ser	
35 40 45	
Ile Pro Arg Ser Phe Ser Tyr Leu Ile Trp Asp Ile Ile Ile Ala Ser	
50 55 60	
Cys Phe Tyr Tyr Xaa Ala Thr Thr Tyr Phe Pro Leu Leu Pro His Pro	
65 70 75 80	
Leu Ser Tyr Phe Ala Trp Pro Leu Tyr Trp Ala Cys Gln Gly Cys Val	
85 90 95	
Leu Thr Gly Val Trp Val Ile Ala His Lys Cys Gly His His Ala Phe	
100 105 110	
Ser Asp Tyr Gln Trp Leu Asp Asp Thr Val Gly Leu Ile Phe His Ser	
115 120 125	
Phe Leu Leu Val Pro Tyr Phe Ser Trp Lys Tyr Ser His Arg Ser His	
130 135 140	

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His Ser Asn Thr Gly Ser Leu Glu Arg Asp Glu Val Phe Val Pro Lys
145                      150                      155                      160

Lys Lys Ser Asp Ile Lys Trp Tyr Gly Lys Tyr Leu Asn Asn Pro Leu
                      165                      170                      175

Gly Arg Thr Val Met Leu Thr Val Gln Phe Thr Leu Gly Trp Pro Leu
                      180                      185                      190

Tyr Leu Ala Phe Asn Val Ser Gly Arg Pro Tyr Asp Gly Gly Phe Arg
                      195                      200                      205

Cys His Phe His Pro Asn Ala Pro Ile Tyr Asn Asp Arg Glu Arg Leu
210                      215                      220

Gln Ile Tyr Ile Ser Asp Ala Gly Ile Leu Ala Val Cys Tyr Gly Leu
225                      230                      235                      240

Phe Arg Tyr Ala Ala Gly Gln Gly Val Ala Ser Met Val Cys Phe Tyr
                      245                      250                      255

Gly Val Pro Leu Leu Ile Val Asn Gly Phe Leu Val Leu Ile Thr Tyr
260                      265                      270

Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp
275                      280                      285

Asp Trp Phe Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile
290                      295                      300

Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His
305                      310                      315                      320

Pro Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala
                      325                      330                      335

Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Phe Asp Gly Thr Pro Val
                      340                      345                      350

Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro
                      355                      360                      365

Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu
370                      375                      380

```

## (2) INFORMATION FOR SEQ ID NO:5:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1155 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA

## (iii) HYPOTHETICAL: NO

## (iv) ANTI-SENSE: NO

## (vi) ORIGINAL SOURCE:

- (A) ORGANISM: Brassica napus

## (ix) FEATURE:

- (D) OTHER INFORMATION: Wild type F form.



## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

ATG	GGT	GCA	GGT	GGA	AGA	ATG	CAA	GTG	TCT	CCT	CCC	TCC	AAA	AAG	TCT	48
Met	Gly	Ala	Gly	Gly	Arg	Met	Gln	Val	Ser	Pro	Pro	Ser	Lys	Lys	Ser	
1				5					10					15		
GAA	ACC	GAC	AAC	ATC	AAG	CGC	GTA	CCC	TGC	GAG	ACA	CCG	CCC	TTC	ACT	96
Glu	Thr	Asp	Asn	Ile	Lys	Arg	Val	Pro	Cys	Glu	Thr	Pro	Pro	Phe	Thr	
			20					25					30			
GTC	GGA	GAA	CTC	AAG	AAA	GCA	ATC	CCA	CCG	CAC	TGT	TTC	AAA	CGC	TCG	144
Val	Gly	Glu	Leu	Lys	Lys	Ala	Ile	Pro	Pro	His	Cys	Phe	Lys	Arg	Ser	
			35				40						45			
ATC	CCT	CGC	TCT	TTC	TCC	TAC	CTC	ATC	TGG	GAC	ATC	ATC	ATA	GCC	TCC	192
Ile	Pro	Arg	Ser	Phe	Ser	Tyr	Leu	Ile	Trp	Asp	Ile	Ile	Ile	Ala	Ser	
	50					55					60					
TGC	TTC	TAC	TAC	GTC	GCC	ACC	ACT	TAC	TTC	CCT	CTC	CTC	CCT	CAC	CCT	240
Cys	Phe	Tyr	Tyr	Val	Ala	Thr	Thr	Tyr	Phe	Pro	Leu	Leu	Pro	His	Pro	
	65				70					75					80	
CTC	TCC	TAC	TTC	GCC	TGG	CCT	CTC	TAC	TGG	GCC	TGC	CAG	GGC	TGC	GTC	288
Leu	Ser	Tyr	Phe	Ala	Trp	Pro	Leu	Tyr	Trp	Ala	Cys	Gln	Gly	Cys	Val	
				85					90				95			
CTA	ACC	GGC	GTC	TGG	GTC	ATA	GCC	CAC	GAG	TGC	GGC	CAC	CAC	GCC	TTC	336
Leu	Thr	Gly	Val	Trp	Val	Ile	Ala	His	Glu	Cys	Gly	His	His	Ala	Phe	
			100					105					110			
AGC	GAC	TAC	CAG	TGG	CTG	GAC	GAC	ACC	GTC	GGC	CTC	ATC	TTC	CAC	TCC	384
Ser	Asp	Tyr	Gln	Trp	Leu	Asp	Asp	Thr	Val	Gly	Leu	Ile	Phe	His	Ser	
		115				120						125				
TTC	CTC	CTC	GTC	CCT	TAC	TTC	TCC	TGG	AAG	TAC	AGT	CAT	CGA	CGC	CAC	432
Phe	Leu	Leu	Val	Pro	Tyr	Phe	Ser	Trp	Lys	Tyr	Ser	His	Arg	Arg	His	
	130					135					140					
CAT	TCC	AAC	ACT	GGC	TCC	CTC	GAG	AGA	GAC	GAA	GTG	TTT	GTC	CCC	AAG	480
His	Ser	Asn	Thr	Gly	Ser	Leu	Glu	Arg	Asp	Glu	Val	Phe	Val	Pro	Lys	
	145				150				155						160	
AAG	AAG	TCA	GAC	ATC	AAG	TGG	TAC	GGC	AAG	TAC	CTC	AAC	AAC	CCT	TTG	528
Lys	Lys	Ser	Asp	Ile	Lys	Trp	Tyr	Gly	Lys	Tyr	Leu	Asn	Asn	Pro	Leu	
				165					170					175		
GGA	CGC	ACC	GTG	ATG	TTA	ACG	GTT	CAG	TTC	ACT	CTC	GGC	TGG	CCT	TTG	576
Gly	Arg	Thr	Val	Met	Leu	Thr	Val	Gln	Phe	Thr	Leu	Gly	Trp	Pro	Leu	
			180					185					190			
TAC	TTA	GCC	TTC	AAC	GTC	TCG	GGG	AGA	CCT	TAC	GAC	GGC	GGC	TTC	GCT	624
Tyr	Leu	Ala	Phe	Asn	Val	Ser	Gly	Arg	Pro	Tyr	Asp	Gly	Gly	Phe	Ala	
		195					200					205				
TGC	CAT	TTC	CAC	CCC	AAC	GCT	CCC	ATC	TAC	AAC	GAC	CGC	GAG	CGT	CTC	672
Cys	His	Phe	His	Pro	Asn	Ala	Pro	Ile	Tyr	Asn	Asp	Arg	Glu	Arg	Leu	
	210					215					220					
CAG	ATA	TAC	ATC	TCC	GAC	GCT	GGC	ATC	CTC	GCC	GTC	TGC	TAC	GGT	CTC	720
Gln	Ile	Tyr	Ile	Ser	Asp	Ala	Gly	Ile	Leu	Ala	Val	Cys	Tyr	Gly	Leu	
	225				230					235					240	
TAC	CGC	TAC	GCT	GCT	GTC	CAA	GGA	GTT	GCC	TCG	ATG	GTC	TGC	TTC	TAC	768
Tyr	Arg	Tyr	Ala	Ala	Val	Gln	Gly	Val	Ala	Ser	Met	Val	Cys	Phe	Tyr	
				245					250					255		
GGA	GTT	CCG	CTT	CTG	ATT	GTC	AAT	GGG	TTC	TTA	GTT	TTG	ATC	ACT	TAC	816
Gly	Val	Pro	Leu	Leu	Ile	Val	Asn	Gly	Phe	Leu	Val	Leu	Ile	Thr	Tyr	
			260					265					270			

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TTG CAG CAC ACG CAT CCT TCC CTG CCT CAC TAT GAC TCG TCT GAG TGG	864
Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp	
275 280 285	
GAT TGG TTG AGG GGA GCT TTG GCC ACC GTT GAC AGA GAC TAC GGA ATC	912
Asp Trp Leu Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile	
290 295 300	
TTG AAC AAG GTC TTC CAC AAT ATC ACG GAC ACG CAC GTG GCG CAT CAC	960
Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His	
305 310 315 320	
CTG TTC TCG ACC ATG CCG CAT TAT CAT GCG ATG GAA GCT ACG AAG GCG	1008
Leu Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala	
325 330 335	
ATA AAG CCG ATA CTG GGA GAG TAT TAT CAG TTG CAT GGG ACG CCG GTG	1056
Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Leu His Gly Thr Pro Val	
340 345 350	
GTT AAG GCG ATG TGG AGG GAG GCG AAG GAG TGT ATC TAT GTG GAA CCG	1104
Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro	
355 360 365	
GAC AGG CAA GGT GAG AAG AAA GGT GTG TTC TGG TAC AAC AAT AAG TTA T	1153
Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu	
370 375 380	
GA	1155

## (2) INFORMATION FOR SEQ ID NO:6:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 384 amino acids  
 (B) TYPE: amino acid  
 (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: protein

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Met Gly Ala Gly Gly Arg Met Gln Val Ser Pro Pro Ser Lys Lys Ser	
1 5 10 15	
Glu Thr Asp Asn Ile Lys Arg Val Pro Cys Glu Thr Pro Pro Phe Thr	
20 25 30	
Val Gly Glu Leu Lys Lys Ala Ile Pro Pro His Cys Phe Lys Arg Ser	
35 40 45	
Ile Pro Arg Ser Phe Ser Tyr Leu Ile Trp Asp Ile Ile Ile Ala Ser	
50 55 60	
Cys Phe Tyr Tyr Val Ala Thr Thr Tyr Phe Pro Leu Leu Pro His Pro	
65 70 75 80	
Leu Ser Tyr Phe Ala Trp Pro Leu Tyr Trp Ala Cys Gln Gly Cys Val	
85 90 95	
Leu Thr Gly Val Trp Val Ile Ala His Glu Cys Gly His His Ala Phe	
100 105 110	
Ser Asp Tyr Gln Trp Leu Asp Asp Thr Val Gly Leu Ile Phe His Ser	
115 120 125	
Phe Leu Leu Val Pro Tyr Phe Ser Trp Lys Tyr Ser His Arg Arg His	
130 135 140	

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His 145	Ser	Asn	Thr	Gly	Ser 150	Leu	Glu	Arg	Asp	Glu 155	Val	Phe	Val	Pro	Lys 160
Lys	Lys	Ser	Asp	Ile 165	Lys	Trp	Tyr	Gly	Lys 170	Tyr	Leu	Asn	Asn	Pro	Leu 175
Gly	Arg	Thr	Val 180	Met	Leu	Thr	Val	Gln 185	Phe	Thr	Leu	Gly	Trp 190	Pro	Leu
Tyr	Leu	Ala 195	Phe	Asn	Val	Ser	Gly 200	Arg	Pro	Tyr	Asp	Gly 205	Gly	Phe	Ala
Cys	His 210	Phe	His	Pro	Asn	Ala 215	Pro	Ile	Tyr	Asn	Asp 220	Arg	Glu	Arg	Leu
Gln 225	Ile	Tyr	Ile	Ser	Asp 230	Ala	Gly	Ile	Leu	Ala 235	Val	Cys	Tyr	Gly	Leu 240
Tyr	Arg	Tyr	Ala	Ala 245	Val	Gln	Gly	Val	Ala 250	Ser	Met	Val	Cys	Phe 255	Tyr
Gly	Val	Pro	Leu 260	Leu	Ile	Val	Asn	Gly 265	Phe	Leu	Val	Leu	Ile 270	Thr	Tyr
Leu	Gln	His 275	Thr	His	Pro	Ser	Leu 280	Pro	His	Tyr	Asp	Ser 285	Ser	Glu	Trp
Asp	Trp 290	Leu	Arg	Gly	Ala	Leu 295	Ala	Thr	Val	Asp	Arg 300	Asp	Tyr	Gly	Ile
Leu 305	Asn	Lys	Val	Phe	His 310	Asn	Ile	Thr	Asp	Thr 315	His	Val	Ala	His 320	His
Leu	Phe	Ser	Thr	Met 325	Pro	His	Tyr	His	Ala 330	Met	Glu	Ala	Thr	Lys 335	Ala
Ile	Lys	Pro	Ile 340	Leu	Gly	Glu	Tyr	Tyr	Gln 345	Leu	His	Gly	Thr 350	Pro	Val
Val	Lys	Ala 355	Met	Trp	Arg	Glu	Ala 360	Lys	Glu	Cys	Ile	Tyr 365	Val	Glu	Pro
Asp	Arg 370	Gln	Gly	Glu	Lys	Lys 375	Gly	Val	Phe	Trp	Tyr	Asn 380	Asn	Lys	Leu

## (2) INFORMATION FOR SEQ ID NO:7:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1155 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

## (ii) MOLECULE TYPE: DNA

## (iii) HYPOTHETICAL: NO

## (iv) ANTI-SENSE: NO

## (vi) ORIGINAL SOURCE:

- (A) ORGANISM: Brassica napus

## (vii) IMMEDIATE SOURCE:

- (B) CLONE: Q508

## (ix) FEATURE:

- (D) OTHER INFORMATION: T to A transversion mutation at nucleotide 515 of the F form.

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## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

ATG Met 1	GGT Gly	GCA Ala	GGT Gly	GGA Gly 5	AGA Arg	ATG Met	CAA Gln	GTG Val	TCT Ser 10	CCT Pro	CCC Pro	TCC Ser	AAA Lys	AAG Lys 15	TCT Ser	48
GAA Glu	ACC Thr	GAC Asp	AAC Asn 20	ATC Ile	AAG Lys	CGC Arg	GTA Val	CCC Pro 25	TGC Cys	GAG Glu	ACA Thr	CCG Pro	CCC Pro 30	TTC Phe	ACT Thr	96
GTC Val	GGA Gly 35	GAA Glu	CTC Leu	AAG Lys	AAA Lys	GCA Ala	ATC Ile 40	CCA Pro	CCG Pro	CAC His	TGT Cys	TTC Phe 45	AAA Lys	CGC Arg	TCG Ser	144
ATC Ile 50	CCT Pro	CGC Arg	TCT Ser	TTC Phe	TCC Ser	TAC Tyr 55	CTC Leu	ATC Ile	TGG Trp	GAC Asp	ATC Ile 60	ATC Ile	ATA Ile	GCC Ala	TCC Ser	192
TGC Cys 65	TTC Phe	TAC Tyr	TAC Tyr	GTC Val	GCC Ala 70	ACC Thr	ACT Thr	TAC Tyr	TTC Phe 75	CCT Pro	CTC Leu	CTC Leu	CCT Pro	CAC His	CCT Pro 80	240
CTC Leu	TCC Ser	TAC Tyr	TTC Phe	GCC Ala 85	TGG Trp	CCT Pro	CTC Leu	TAC Tyr	TGG Trp 90	GCC Ala	TGC Cys	CAG Gln	GGC Gly	TGC Cys 95	GTC Val	288
CTA Leu	ACC Thr	GGC Gly	GTC Val 100	TGG Trp	GTC Val	ATA Ile	GCC Ala	CAC His 105	GAG Glu	TGC Cys	GGC Gly	CAC His 110	CAC His	GCC Ala	TTC Phe	336
AGC Ser	GAC Asp	TAC Tyr 115	CAG Gln	TGG Trp	CTG Leu	GAC Asp 120	GAC Asp	ACC Thr	GTC Val	GGC Gly	CTC Leu 125	ATC Ile	TTC Phe	CAC His	TCC Ser	384
TTC Phe 130	CTC Leu	CTC Leu	GTC Val	CCT Pro	TAC Tyr	TTC Phe 135	TCC Ser	TGG Trp	AAG Lys	TAC Tyr	AGT Ser 140	CAT His	CGA Arg	CGC Arg	CAC His	432
CAT His 145	TCC Ser	AAC Asn	ACT Thr	GGC Gly	TCC Ser 150	CTC Leu	GAG Glu	AGA Arg	GAC Asp 155	GAA Glu	GTG Val	TTT Phe	GTC Val	CCC Pro	AAG Lys 160	480
AAG Lys	AAG Lys	TCA Ser	GAC Asp	ATC Ile 165	AAG Lys	TGG Trp	TAC Tyr	GGC Gly	AAG Lys 170	TAC Tyr	CAC His	AAC Asn	AAC Asn	CCT Pro 175	TTG Leu	528
GGA Gly	CGC Arg	ACC Thr	GTG Val 180	ATG Met	TTA Leu	ACG Thr	GTT Val	CAG Gln 185	TTC Phe	ACT Thr	CTC Leu	GGC Gly	TGG Trp 190	CCT Pro	TTG Leu	576
TAC Tyr	TTA Leu	GCC Ala 195	TTC Phe	AAC Asn	GTC Val	TCG Ser	GGG Gly 200	AGA Arg	CCT Pro	TAC Tyr	GAC Asp	GGC Gly 205	GGC Gly	TTC Phe	GCT Ala	624
TGC Cys 210	CAT His	TTC Phe	CAC His	CCC Pro	AAC Asn 215	GCT Ala	CCC Pro	ATC Ile	TAC Tyr	AAC Asn	GAC Asp 220	CGC Arg	GAG Glu	CGT Arg	CTC Leu	672
CAG Gln 225	ATA Ile	TAC Tyr	ATC Ile	TCC Ser	GAC Asp 230	GCT Ala	GGC Gly	ATC Ile	CTC Leu	GCC Ala 235	GTC Val	TGC Cys	TAC Tyr	GGT Gly	CTC Leu 240	720
TAC Tyr	CGC Arg	TAC Tyr	GCT Ala 245	GCT Ala	GTC Val	CAA Gln	GGA Gly	GTT Val	GCC Ala 250	TCG Ser	ATG Met	GTC Val	TGC Cys	TTC Phe 255	TAC Tyr	768
GGA Gly	GTT Val	CCG Pro	CTT Leu 260	CTG Leu	ATT Ile	GTC Val	AAT Asn	GGG Gly 265	TTC Phe	TTA Leu	GTT Val	TTG Leu	ATC Ile 270	ACT Thr	TAC Tyr	816

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TTG CAG CAC ACG CAT CCT TCC CTG CCT CAC TAT GAC TCG TCT GAG TGG	864
Leu Gln His Thr His Pro Ser Leu Pro His Tyr Asp Ser Ser Glu Trp	
275 280 285	
GAT TGG TTG AGG GGA GCT TTG GCC ACC GTT GAC AGA GAC TAC GGA ATC	912
Asp Trp Leu Arg Gly Ala Leu Ala Thr Val Asp Arg Asp Tyr Gly Ile	
290 295 300	
TTG AAC AAG GTC TTC CAC AAT ATC ACG GAC ACG CAC GTG GCG CAT CAC	960
Leu Asn Lys Val Phe His Asn Ile Thr Asp Thr His Val Ala His His	
305 310 315 320	
CTG TTC TCG ACC ATG CCG CAT TAT CAT GCG ATG GAA GCT ACG AAG GCG	1008
Leu Phe Ser Thr Met Pro His Tyr His Ala Met Glu Ala Thr Lys Ala	
325 330 335	
ATA AAG CCG ATA CTG GGA GAG TAT TAT CAG TTG CAT GGG ACG CCG GTG	1056
Ile Lys Pro Ile Leu Gly Glu Tyr Tyr Gln Leu His Gly Thr Pro Val	
340 345 350	
GTT AAG GCG ATG TGG AGG GAG GCG AAG GAG TGT ATC TAT GTG GAA CCG	1104
Val Lys Ala Met Trp Arg Glu Ala Lys Glu Cys Ile Tyr Val Glu Pro	
355 360 365	
GAC AGG CAA GGT GAG AAG AAA GGT GTG TTC TGG TAC AAC AAT AAG TTA T	1153
Asp Arg Gln Gly Glu Lys Lys Gly Val Phe Trp Tyr Asn Asn Lys Leu	
370 375 380	
GA	1155

## (2) INFORMATION FOR SEQ ID NO:8:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 384 amino acids
  - (B) TYPE: amino acid
  - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

Met Gly Ala Gly Gly Arg Met Gln Val Ser Pro Pro Ser Lys Lys Ser
1 5 10 15
Glu Thr Asp Asn Ile Lys Arg Val Pro Cys Glu Thr Pro Pro Phe Thr
20 25 30
Val Gly Glu Leu Lys Lys Ala Ile Pro Pro His Cys Phe Lys Arg Ser
35 40 45
Ile Pro Arg Ser Phe Ser Tyr Leu Ile Trp Asp Ile Ile Ala Ser
50 55 60
Cys Phe Tyr Tyr Val Ala Thr Thr Tyr Phe Pro Leu Leu Pro His Pro
65 70 75 80
Leu Ser Tyr Phe Ala Trp Pro Leu Tyr Trp Ala Cys Gln Gly Cys Val
85 90 95
Leu Thr Gly Val Trp Val Ile Ala His Glu Cys Gly His His Ala Phe
100 105 110
Ser Asp Tyr Gln Trp Leu Asp Asp Thr Val Gly Leu Ile Phe His Ser
115 120 125
Phe Leu Leu Val Pro Tyr Phe Ser Trp Lys Tyr Ser His Arg Arg His
130 135 140

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His 145	Ser	Asn	Thr	Gly	Ser 150	Leu	Glu	Arg	Asp	Glu 155	Val	Phe	Val	Pro	Lys 160
Lys	Lys	Ser	Asp	Ile 165	Lys	Trp	Tyr	Gly	Lys 170	Tyr	His	Asn	Asn	Pro	Leu 175
Gly	Arg	Thr	Val	Met 180	Leu	Thr	Val	Gln 185	Phe	Thr	Leu	Gly	Trp 190	Pro	Leu
Tyr	Leu	Ala	Phe	Asn	Val	Ser	Gly 200	Arg	Pro	Tyr	Asp	Gly 205	Gly	Phe	Ala
Cys	His 210	Phe	His	Pro	Asn	Ala 215	Pro	Ile	Tyr	Asn	Asp 220	Arg	Glu	Arg	Leu
Gln 225	Ile	Tyr	Ile	Ser	Asp 230	Ala	Gly	Ile	Leu	Ala 235	Val	Cys	Tyr	Gly	Leu 240
Tyr	Arg	Tyr	Ala	Ala 245	Val	Gln	Gly	Val	Ala 250	Ser	Met	Val	Cys	Phe	Tyr 255
Gly	Val	Pro	Leu 260	Leu	Ile	Val	Asn	Gly 265	Phe	Leu	Val	Leu	Ile 270	Thr	Tyr
Leu	Gln 275	His	Thr	His	Pro	Ser	Leu 280	Pro	His	Tyr	Asp	Ser 285	Ser	Glu	Trp
Asp	Trp 290	Leu	Arg	Gly	Ala	Leu 295	Ala	Thr	Val	Asp	Arg 300	Asp	Tyr	Gly	Ile
Leu 305	Asn	Lys	Val	Phe	His 310	Asn	Ile	Thr	Asp	Thr 315	His	Val	Ala	His	His 320
Leu	Phe	Ser	Thr	Met 325	Pro	His	Tyr	His	Ala 330	Met	Glu	Ala	Thr	Lys	Ala 335
Ile	Lys	Pro	Ile 340	Leu	Gly	Glu	Tyr	Tyr 345	Gln	Leu	His	Gly	Thr 350	Pro	Val
Val	Lys	Ala 355	Met	Trp	Arg	Glu	Ala 360	Lys	Glu	Cys	Ile	Tyr 365	Val	Glu	Pro
Asp	Arg 370	Gln	Gly	Glu	Lys	Lys 375	Gly	Val	Phe	Trp	Tyr 380	Asn	Asn	Lys	Leu

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WHAT IS CLAIMED IS:

1. An isolated nucleic acid fragment comprising a sequence of at least about 10 nucleotides from a *Brassicaceae* or *Helianthus* delta-12 fatty acid desaturase gene having at least one mutation, wherein said gene is effective for altering fatty acid composition in *Brassicaceae* or *Helianthus* seeds and wherein said sequence includes said at least one mutation.
2. The nucleic acid fragment of claim 1, wherein said sequence comprises a full-length coding sequence of said gene.
3. The nucleic acid fragment of claim 1, wherein said mutant desaturase gene encodes a microsomal gene product.
4. The nucleic acid fragment of claim 1, wherein said at least one mutation comprises a mutation in a region of said desaturase gene encoding a His-Glu-Cys-Gly-His amino acid motif.
5. The nucleic acid fragment of claim 4, wherein said at least one mutation comprises a non-conservative amino acid substitution in said region.
6. The nucleic acid fragment of claim 5, wherein said at least one mutation comprises the sequence His-Lys-Cys-Gly-His.
7. The nucleic acid fragment of claim 1, wherein said mutant desaturase gene is from a *Brassica napus* plant.
8. The nucleic acid fragment of claim 1, wherein said gene is the D form of a *Brassicaceae* microsomal gene.

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9. The nucleic acid fragment of claim 1, wherein said at least at least one mutation comprises the sequence Lys-Tyr-His-Asn-Asn-Pro.

10. A plant of the *Brassicaceae* or *Helianthus* families  
5 other than *Brassica napus*, said plant containing a sequence of at least 10 nucleotides from a delta-12 fatty acid desaturase gene having at least one mutation, said at least one mutation in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif and wherein said mutation  
10 confers an altered fatty acid composition in seeds of said plant.

11. The plant of claim 10, wherein said plant contains a full-length coding sequence of said mutant gene.

12. The plant of claim 10, wherein said motif  
15 comprises the sequence His-Glu-Cys-Gly-His.

13. The plant of claim 10, wherein said gene is from a *Brassica napus* plant.

14. The plant of claim 10, wherein said plant is a *Brassica rapa* plant.

20 15. An isolated nucleic acid fragment comprising a sequence of at least about 10 nucleotides from a *Brassicaceae* or *Helianthus* delta-15 fatty acid desaturase gene having at least one mutation, wherein said gene is effective for altering fatty acid composition in  
25 *Brassicaceae* or *Helianthus* seeds and wherein said sequence includes said at least one mutation.



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16. The nucleic acid fragment of claim 15, wherein said sequence comprises a full-length coding sequence of said gene.
17. The nucleic acid fragment of claim 15, wherein  
5 said at least one mutation comprises a mutation in a region of said desaturase gene encoding a His-Asp-Cys-Gly-His amino acid motif.
18. The nucleic acid fragment of claim 15, wherein said mutant desaturase gene is from a *Brassica napus*  
10 plant.
19. A *Brassicaceae* or *Helianthus* plant containing a sequence of at least 10 nucleotides from a delta-15 fatty acid desaturase gene having at least one mutation, said at least one mutation in a region encoding a His-Xaa-Xaa-  
15 Xaa-His amino acid motif and wherein said mutation confers an altered fatty acid composition in seeds of said plant.
20. The plant of claim 19, wherein said plant contains a full-length coding sequence of said mutant gene.
- 20 21. The plant of claim 19, wherein said motif comprises the sequence His-Asp-Cys-Gly-His.
22. The plant of claim 19, wherein said mutant desaturase gene is from a *Brassica napus* plant.
23. The plant of claim 19, wherein said plant is a  
25 *Brassica napus* plant.
24. A *Brassicaceae* or *Helianthus* plant containing:

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- 5 a) a sequence of at least about 10 nucleotides from a delta-12 fatty acid desaturase gene having at least one mutation, said at least one delta-12 gene mutation in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif;
- 10 b) a sequence of at least 10 nucleotides from a delta-15 fatty acid desaturase gene having at least one mutation, said at least one delta-15 gene mutation in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif, said delta-12 gene mutation and said delta-15 gene mutation conferring an altered fatty acid composition in seeds of said plant.

25. A *Brassicaceae* or *Helianthus* plant containing a  
15 sequence of at least about 10 nucleotides from a delta-12 fatty acid desaturase gene having at least one mutation, said at least one mutation in a region encoding a Tyr-Leu-Asn-Asn-Pro amino acid motif and wherein said mutation confers an altered fatty acid composition in  
20 seeds of said plant.

26. A vegetable oil extracted from seeds produced by the plant of claim 10.

27. The oil of claim 26, wherein said oil has, following crushing and extraction of said seeds, from  
25 about 1% to about 10% linoleic acid based on total fatty acid composition.

28. The oil of claim 26, wherein said oil has from about 69% to about 90% oleic acid based on total fatty acid composition.

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29. A vegetable oil extracted from seeds produced by the plant of claim 19.

30. The oil of claim 29, wherein said oil has, following crushing and extraction of said seeds, from  
5 about 0.5% to about 10%  $\alpha$ -linolenic acid based on total fatty acid composition.

31. A vegetable oil extracted from seeds produced by the plant of claim 24.

32. A vegetable oil extracted from seeds produced by  
10 the plant of claim 25.

33. A method for producing a *Brassicaceae* or *Helianthus* plant line, comprising the steps of:

- a) inducing mutagenesis in cells of a starting variety of a *Brassicaceae* or *Helianthus* species;
- 15 b) obtaining one or more progeny plants from said cells;
- c) identifying at least one of said progeny plant that contains a delta-12 fatty acid desaturase gene having at least one mutation, said  
20 at least one mutation in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif; and
- d) producing said plant line from said at least one progeny plant by self- or cross-pollination, said plant line having said at least one delta-12  
25 gene mutation.

34. The method of claim 33, wherein said plant line produces seeds yielding an oil having a stabilized linoleic acid content from about 1% to about 14%.

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35. The method of claim 33, further comprising the steps of:

- e) inducing mutagenesis in cells of said plant line;
- 5 f) obtaining one or more progeny plants from said plant line cells;
- g) identifying at least one of said plant line progeny plants that contains a delta-15 fatty acid desaturase gene having at least one delta-15 gene mutation, said at least one delta-15 gene mutation  
10 in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif;
- h) producing a second plant line from said at least one plant line progeny plant by self- or  
15 cross-pollination, said second plant line having said at least one delta-12 gene mutation and said at least one delta-15 gene mutation.

36. The method of claim 33, wherein said starting variety is a *Brassica napus* variety.

20 37. The method of claim 36, wherein said mutation is in a first form of delta-12 fatty acid desaturase.

38. The method of claim 37, further comprising the step of crossing a plant of said plant line to a plant having a mutation in a second form of delta-12 fatty acid  
25 desaturase.

39. The method of claim 38, wherein said second mutation is in a region other than a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif.

40. The method of claim 36, further comprising the  
30 steps of:

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- e) inducing mutagenesis in cells of said plant line;
- f) obtaining one or more progeny plants from said plant line cells;
- 5 g) identifying at least one of said plant line progeny plants that contains a second delta-12 fatty acid desaturase gene having at least one mutation, said second gene mutation in a region other than a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif; and
- 10 h) producing a second plant line from said at least one plant line progeny plant by self- or cross-pollination, said second plant line having said first delta-12 gene mutation and said second
- 15 delta-12 gene mutation.

41. A method for producing a *Brassicaceae* or *Helianthus* plant line, comprising the steps of:
- a) inducing mutagenesis in cells of a starting variety of a *Brassicaceae* or *Helianthus* species;
  - 20 b) obtaining one or more progeny plants from said cells;
  - c) identifying at least one of said progeny plants that contains a delta-15 fatty acid desaturase gene having at least one mutation, said
  - 25 at least one mutation in a region encoding a His-Xaa-Xaa-Xaa-His amino acid motif; and
  - d) producing said plant line from said at least one progeny plant by self- or cross-pollination, said plant line having said delta-15 gene
  - 30 mutation.

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/20090**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : A01H 1/06, 5/10, 1/00; C12N 15/00; C07C 57/02, 57/03, 53/126

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 800/230, 200, 205, 255, DIG. 17, DIG 69; 435/172.1, 172.3; 47/58, DIG. 1; 554/8, 9, 223, 224; 426/601, 615, 629

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ROBBELEN. Genetical and Physiological Investigations on Mutants for Polyenoic Fatty Acids in Rapeseed, Brassica napus L. Z. Pflanzenzuchtg. 1975. Vol. 73, pages 93-105, especially page 94.	10-14 and 19-41
Y	WO 91/15578 A1 (PIONEER HI-BRED INTERNATIONAL, INC.) 17 October 1991, pages 1-56, especially pages 8-40.	10-41
Y	US 5,434,283 A (WONG et al.) 18 June 1995, columns 1-20, especially column 4, line 50 to column 19, line 8.	10-41
Y	EP 0 323 753 A1 (ALLELIX INC.) 12 July 1989, pages 2-12, especially pages 7-10.	10-41

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search

20 MARCH 1997

Date of mailing of the international search report

08 MAY 1997

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# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US96/20090

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	TOPFER et al. Modification of Plant Lipid Synthesis. SCIENCE, Vol. 268, 05 May 1995, pages 681-686.	1-9, 10-14, 19-25 and 33-41
Y	SCARTH et al. STELLAR LOW LINOLENIC -HIGH LINOLEIC ACID SUMMER RAPE. Can. J. Plant Sci. Apr. 1988, Vol. 68, pages 509-511.	10-14, 19-25 and 26-32
Y	US 4,948,811 A (SPINNER et al.) 14 August 1990, columns 1-8.	26-32
Y	US 5,387,758 A (WONG et al.) 07 February 1995, columns 2-24, especially column 11, line 25 to column 24, line 26.	10-41
Y	WO 93/12245 A1 (E.I. DU PONT DE NEMOURS AND COMPANY) 10 June 1993, pages 1-163, especially pages 25 to 85.	1-41

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US96/20090

### A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

800/230, 200, 205, 255, DIG. 17, DIG 69; 435/172.1, 172.3; 47/58, DIG. 1; 554/8, 9, 223, 224; 426/601, 615, 629

### B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

APS, BIOSIS, DIALOG.

search terms: nucleic acid, delta 12 fatty acid desaturase, delta 9 fatty acid desaturase, Brassica napus, Brassicaceae, Helianthus, mutagenesis, mutation breeding, linoleic, oleic, alpha linolenic.